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AND

RECORD OF TRANSACTIONS.

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THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

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Issue of Journal. The Journal appears in four parts per sessional volume, viz. in January, April, July and October. A brochure describing the origin, progress and purposes of the Institution, and comprising also the Memorandum and Articles of Association, the By-Laws and Regulations of the Institution, the Library Catalogue to date (with subject index), and the List of Members, was published in September, 1915, to be followed periodically by revisions of the Library Catalogue and List of Members. The List of Members brought up to March, 1921, is now issued.

Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of seven shillings and sixpence per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

Changes of Address. It is particularly requested that members notify the Secretary immediately of any change of address; and members are also requested to advise the Parcel Post Department as well as the Letter Office, of any temporary change of address, as, unless this is done, parcel post packets will not be re-addressed; but will be returned to the offices of the Institution in London, thus incurring further expense for postage.

To Authors of Papers. Papers should be written in the third person, and the copy should be carefully corrected by the author before it is presented.

All drawings, diagrams or other illustrations should be sent in a fit state for direct photographic reproduction.

All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible, and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of December, March, June or September as the case may be. Subsequent delivery may be too late for insertion.

The Council desire to draw the attention of authors to the serious increase in the cost of production. Papers, both for the Journal and for communication to the Institution, should be as concise and condensed as possible.

Communications. The Council invite members to submit papers for the forthcoming session. Communications to the Institution will, subject to the approval of the Publication Committee, be published in the Journal.

Appointments Register. A Register will be kept at the Offices of the Institution for the convenience of firms requiring the services of members and for members requiring appointments, but on the distinct understanding that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library is in course of reorganisation in the new premises at No. 5 John Street, Adelphi, and may be consulted between 11 and 4 daily. Extensive additions are being made to the current and standard literature on Petroleum.

Additions since publication of last Journal.

From Department of Mines, Geological Survey, Ottawa, Canada :—

Memoir No. 118. Mineral Deposits between Lillooet and Prince George, British Columbia.

Memoir No. 119. The Reed-wekusko Map-Area Northern Manitoba.

Memoir No. 120. The Hadrosaur Edmontosaurus from the Upper Cretaceous of Alberta.

Memoir No. 121. The Malagash Salt Deposit, Cumberland County, N.S.

Memoir No. 122. Sheep River Gas and Oil Field, Alberta.

Memoir No. 123. Sixtymile and Ladue Rivers Area, Yukon.

Summary Report, 1919, Part C (in duplicate).

Summary Report, 1919, Part E.

Summary Report, 1919, Part F.

Museum Bulletin No. 31. A Contribution to the Description of the Fauna of the Trenton Group.

Production of Coal and Coke in Canada for 1919.

From Canadian Government Trade Commission :—

Oil and Gas in Western Canada.

Petroleum in Western Canada.

Memoir 108. The Mackenzie River Basin. By C. Camsell and W. Malcolm.

From The Bureau of Mines, U.S.

Bulletin 189. Bibliography of Petroleum and Allied Substances in 1918.

Bulletin 191. Quality of Gasoline marketed in the United States (in duplicate.)

Technical Paper 255. Chlorination of Natural Gas.

From U.S. Geological Survey.

Mineral Waters in 1919. By Arthur J. Ellis.

Gems and Precious Stones in 1919. By B. H. Stoddard.

Potash Resources of Nebraska. By W. B. Hicks.

Secondary Metals in 1919. J. P. Dunlop.

Chromite in 1919. By J. S. Driller.

Foreign Graphite in 1919. By A. H. Redfield.

Phosphate Rock near Maxville Granite County, Montana. By J. T. Pardee.

Mineral Resources of the United States. Gypsum in 1919. By Ralph W. Stone.

The Lance Creek Oil and Gas Field, Niabrara County, Wyoming.

Bulletin 702. Oil Possibilities in and around Baxter Basin in the Rock Springs Uplift, Sweetwater County, Wyoming. By A. R. Schultz.

Bulletin 703. Iron and Associated Industries of Lorraine, the Sarre District, Luxemburg, and Belgium. By A. R. Brooks and M. F. la Croix.

Bulletin 716 E. Forty-first Annual Report of the Director of the U.S. Geological Survey to the Secretary of the Interior, for the year ended June 30th, 1920.

Bulletin 716 F. Coal in Eastern Idaho. By George R. Mansfield.

Water supply, Paper 467. Exploratory Drilling for Water, and Use of Ground Water for irrigation in Steptoe Valley, Nevada. By W. O. Clark and C. W. Riddell.

Water supply, Paper 470. Ground Water in the Norwalk, Suffield, and Glastonbury Areas, Connecticut. By H. S. Palmer.

Water supply, Paper 491. Water supply of St. Mary and Milk Rivers, 1898 to 1917. By B. E. Jones and R. J. Burley.

From Egyptian Geological Survey.

Petroleum Research Bulletin No. 6.

Preliminary Geological Report on the Abu-Shaar-el Qibli (Black Hill District). By T. G. Madgwick, A.R.S.M., F. W. Moon, A.M.I.C.E., H. Sadek, B.Sc.

From Home Office :—

Report on an Explosion on the Oil Tank Barge "Warwick" on September 24th, 1920.

From Mr. W. Hamor, Mellon Institute :—

Technical Examination of Crude Petroleum, Petroleum Products, and Natural Gases.

From Major A. Cooper-Key, C.B.

The Storage of Petroleum Spirit (2nd edition).

From Geological Survey, India :—

Volume LI, Part 3.

The attention of members is drawn to the new supplement of the Journal which deals with current Petroleum literature. To make this section of the maximum usefulness it is necessary that there should be full co-operation between chemists, engineers and geologists, and that matter which has inadvertently escaped notice shall be immediately sent in to the Editor. The Institution has been indebted to Mr. Andrew Campbell for the compilation of the bibliography during this past session, and is now under similar obligation to Mr. W. J. Wilson.

Advertisements in the Journal. A limited number of Advertisements of firms interested in the Petroleum Industry may be inserted in the Journal. Application for terms, etc., should be made to the Secretary.

LIST OF ADVERTISERS.

(Members are desired, when making enquiries or placing orders with advertisers, to mention that they have seen their announcement in the Journal.)

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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

Mrs. A. Lloyd Eastlake has presented to the Institution a very fine photograph of the late Sir Boverton Redwood, Bart., which has been placed with those of the other Past Presidents in the Library.

SPECIFICATIONS.

We have received the List of British Standard Specifications and Reports from the British Engineering Standards Association, including a number of matters of interest to the petroleum profession. Copies may be had from 28 Victoria Street, Westminster, London, S.W.1.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS.

The Board of Directors of the American Institute of Mining and Metallurgical Engineers of 29 West 39th Street, New York, and the Council of this Institution of Petroleum Technologists, have entered into a mutual understanding whereby any Technologist being a Member of either Society, possessing the necessary qualifications and desiring to become Members of the Institution or Institute respectively, can apply to the Institute or Institution, and the respective Council's recommendation will be accepted from him in lieu of signatures on an application form duly signed by Members. This arrangement does not in any way modify or do away with the regulations and rights governing election of members by the respective Institute or Institution.

COMMITTEE ON STANDARDIZATION AND NOMENCLATURE.

The Council of the Institution has appointed a Standing Committee to deal with the standardization of tests relating to mineral oils and the nomenclature of naphthology. The Committee is to possess wide powers of co-option and will undoubtedly ask for the assistance and co-operation of those members of the Institution who have special acquaintance with the multifarious tests and estimations now current. Sub-committees will be appointed to deal with groups of tests, and an attempt will be made to put forward an authoritative series of methods of analysis. The urgent need for such work is felt in other countries, and the excellent work already carried out in the United States needs no mention here. On another page of this issue of the Journal it will be noticed that further efforts are being initiated in America.

Members will be kept in touch with the Committee's activities by means of periodical reports in the Journal.

PETROLEUM NOTES AND CORRESPONDENCE.

It has been decided to open columns in the Journal to be devoted to general petroleum notes and to correspondence. Members of the Institution are invited to contribute thereto as occasion warrants.

CRYSTAL PALACE LECTURES ON PETROLEUM.

The Council have arranged to publish in book form a complete series of the Crystal Palace Lectures, which will be rewritten and illustrated with some ninety-two diagrams and plates. The work is to be issued as a Popular Petroleum Book for the general petroleum-reading world, with glossary, statistical tables (including various weights and measures for technical reference), a bibliography and other useful information. The Council are anxious that the members should support this venture, and those members desiring to subscribe to the volume can obtain further information on application to the Secretary.

STANDARDIZATION OF PETROLEUM SPECIFICATIONS.

Organization of the Interdepartmental Committee on Standardization of Petroleum Specifications, which supersedes the war-time committee on the same subject, was effected at the first meeting of the committee held at the Bureau of Mines, Washington, D.C., February 19. In addition, the committee gave its approval to *Bull.* 5 of the old committee, thus continuing in force the specifications on gasoline, kerosene, fuel oils, lubricating oils, signal oils, etc., contained in that bulletin. The committee further decided to adopt the plan of adding a technical sub-committee to handle the details of drawing up and revising specifications and methods of testing. Dr. H. Foster Bain, acting director of the Bureau of Mines, appointed N. A. C. Smith, petroleum chemist, to represent him as chairman of the technical committee.

This new committee was organized in accordance with the following letter from the President to the Secretary of the Interior.

"In view of the desirability of standardized specifications for the supply of petroleum and its products to the United States Government, I approve the formation of an Interdepartmental Committee on Standardization of Petroleum Specifications, to consist of a representative of the Treasury, the War, the Navy, the Post Office, the Interior, the Agriculture, and the Commerce Departments, the Panama Canal, and the Shipping Board.

"Each of the Departments, the Panama Canal and the Shipping Board, is to appoint one member. The function of the Committee is to prepare and adopt specifications for the supply of petroleum and its products to any and all departments, bureaus, agencies, and offices of the Government, and to revise such specifications as need arises, giving due considerations to the amounts and qualities of crude petroleum available.

"It is believed that standardized specifications will be of service in obtaining supplies of petroleum products of satisfactory quality, and will also aid in the conservation of natural resources by encouraging the most efficient utilization of petroleum.

"It is important that the Committee have permanency, and it will be well, therefore, that the representative of the Interior Department be the chairman. Executive Order (2929), dated 31 July, 1918, is hereby rescinded.

(Signed) WOODROW WILSON."

Taken from "Mining and Metallurgy" (American), April, 1921, No. 172.

"TESTING MATERIALS SOCIETY PLANS REPORT ON PETROLEUM SPECIFICATIONS WHICH WILL BEAR IMPORTANTLY ON QUALITY STANDARDS.

"This year has seen by far the greatest activity of the American Society for Testing Materials in the development of tests for petroleum products and lubricants. The need for standardization in this large and rapidly developing industry was recognized by the Executive

Committee a year ago when the scope of Committee D-2 on Lubricants was enlarged to include petroleum products and lubricants. The Committee was reorganized and additional members appointed. It has now 27 producer and 30 non-producer members, a total of 57. The work of the Committee is handled by seventeen sub-committees, some dealing with methods of test and some with specifications. While the Committee has felt the necessity of establishing methods of test before specifications are prepared, five sub-committees, covering petroleum, gas-absorbing oil, paraffin wax, grease, and gasoline, have within their scope the preparation both of testing methods and specifications.

"The Committee has also prepared a revision of the Society's present standard for distillation of paint thinners, making this test applicable to all volatile petroleum products. The main changes made in the present standard are substitution of maximum boiling point for dry point to designate the end point of distillation, and the use of cotton on the thermometer bulb. Both of these changes have already been adopted by the United States Government. The test itself has been elaborated to the greatest possible uniformity in results. This work has been done in collaboration with the Committee D-1 on Preservative Coatings, which drew the present test.

"The Committee has also prepared a revision of the Society's present standard for cloud and pour test, recommending at the same time the withdrawal of the cold test which it considers obsolete.

"The Committee will present to the Society a number of new methods of test to be adopted as tentative. If adopted they will be published and criticisms sought during the coming year from all interested persons. The tests are as follows:—

Melting point of paraffin wax;

Viscosity of fuel oil by means of the Saybolt Furol viscosimeter;

Determination of sulphur or corrosive sulphur compounds;

Determination of sulphur by the bomb method;

Determination of sulphur in illuminating oils;

Determination of precipitation in lubricating oils;

Determination of flash point by the Pensky-Martens instrument (this instrument is the standard instrument for the determination of flash of fuel oil);

Determination of flash point of lubricants by the Cleveland open cup;

Determination of saponification;

Determination of water by distillation, including the excellent apparatus recently devised by the United States Bureau of Mines;

Determination of water and sediment by centrifuge.

In addition the report of the Committee will contain a table of volume-temperature correction factors, a discussion of melting point of petrolatum, and a paper on oil and moisture in paraffin wax."

Extract from "Petroleum," May, 1921.

METHOD OF PACKING SAMPLES OF ASPHALT.

Samples of asphalt if packed in ordinary tins or wooden boxes, or if wrapped in paper or other similar material, invariably stick tenaciously to the container, the surface of the sample being thereby spoilt and the extraction of the sample from the container being a matter of difficulty. If, however, an ordinary tin box, the inside of which has been amalgamated with mercury, be used, the asphalt does not adhere to the metal, so the sample can be readily removed from the tin, with its surface unimpaired.

J. KEWLEY.

HELIUM IN A SAMPLE OF NATURAL GAS.

Helium, next to hydrogen, is the lightest element known, its lifting power being very little less than that of hydrogen itself. Further, it is absolutely non-inflammable, so that it would seem to be the ideal substance for filling balloons and airships. It is present in the atmosphere to an extent of about four parts in one million by volume. It is

also found in certain minerals and in natural waters such as those at Bath. The most promising source, however, seems to be natural gas, and an important series of investigations was carried out towards the end of the war in an endeavour to obtain large amounts of helium (J. C. McLennan, *Journ. Chem. Soc.*, 1920, 117, 923). The helium content of natural gas was found to vary considerably. Thus in Texas the gas may contain from one to two per cent. Within the British Empire the natural gas of Ontario and Alberta, Canada, containing on an average 0·34 to 0·36 % by volume, were found to be the most promising, whilst in Sussex, England, 0·21 % was found. Other gases examined gave less satisfactory results; some contained but traces, whilst from others helium was entirely absent.

It seemed, therefore, of interest to examine a sample of the natural gas from Hurghada, Egypt, to see if this would prove a likely source of helium. The method of examination was as follows. A sample of the gas (sent to England under pressure in iron cylinders) was collected over water in an aspirating bottle. The latter was so arranged that the gas could be passed through a combustion tube about a metre long, filled with copper oxide. The tube and its contents were heated to redness in a gas furnace. By this means the hydrocarbons of the natural gas were oxidised to carbon dioxide and water. The emergent gases were then collected over 40 % potash solution, contained in a suitable apparatus, and the CO_2 thus absorbed.

2070 cc. of the natural gas were passed slowly over the heated copper oxide. During the first passage the volume of the gas was reduced to 450 cc. The gas was returned to the aspirator and passed and repassed over the copper oxide, till its volume was finally reduced to 50 cc. at which stage the copper oxide seemed to cause no further diminution in volume.

This 50 cc. of gas thus obtained were examined for us by Dr. F. Aston of the Cavendish Laboratory. On being examined spectroscopically, the gas only showed very faint helium lines. It was therefore further concentrated. This was effected by passing the gas into a bulb containing absorbent charcoal and surrounded by liquid air. In this bulb all gases excepting helium were condensed. The gas remaining after this treatment was pumped off by means of a mercury pump.

Its volume was estimated at about one-tenth of a cubic centimeter, and on examination it was found to be helium.

Thus from 2070 cc. of natural gas, one-tenth of a cubic centimetre of helium was obtained, corresponding to 0·005 % by volume, or one part in 20,000.

With regard to the other properties of the gas, it burnt with a brightly luminous flame and apparently contained about 97 % of combustible matter.

J. E. G. HARRIS.

ROYAL SCHOOL OF MINES FRECHEVILLE RESEARCH FELLOWSHIPS.

The Imperial College of Science and Technology, South Kensington, London, S.W. 7, with which the Royal School of Mines is incorporated, is offering two Research Fellowships of £300 a year each, tenable for one year and possibly renewable for a second year, to aid in carrying out any investigation or research connected with Mining, Mining Geology, Metallurgy, or the Technology of Oil, which in the opinion of the Selection Committee is of sufficient use or promise.

Applicants who may be Associates of the Royal School of Mines or others, and preferably men with some practical experience, should apply in writing to the Secretary of the College (from whom further particulars may be obtained) before 1st September, 1921, giving the nature of the proposed investigation, qualifications for the work and references.

It is anticipated that the Committee will make the awards by the end of November, so that the Fellowships and work may begin on 1st January, 1922. Holders will be expected to devote their whole time to the work which may be conducted at the Imperial College or in special circumstances elsewhere at the discretion of the Committee.

The Fifty-third General Meeting of the Institution was held in the rooms of the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday evening, 15th February, 1921, Sir Frederick Black, K.C.B., President, in the Chair.

The President, at the opening of the meeting, said he had been requested by the Secretary to remind the members that they should send in to the Institution as early as possible any changes in their addresses and particulars of any titles or honours that had been conferred upon them, in order that the list of members, which would be issued immediately, might be accurate.

Notice was also being sent out calling a Special Meeting of the Institution to be held on Tuesday, 22nd February, in the following terms: "The President and Council, in view of the rapidly increasing membership and the present opportunities of extending the usefulness of the Institution, feel that the time is now opportune for a discussion amongst all those associated with the Institution as to the best steps to be taken to add to its value and efficiency. They have therefore decided that the above special meeting shall be devoted to this object. Under the circumstances it will be recognized that only members, associate-members, students, and associates of the Institution will be eligible to attend at the meeting, and on this occasion guests will not be invited." With that notice there was also being sent out a notice of the Annual Dinner, which would be held in the Connaught Rooms on the 17th March next. In view of the increase in the number of members, the Council had been bold enough to anticipate a bigger attendance than at the last Dinner, and they had therefore taken the large room at the Connaught Rooms, so that there would be plenty of accommodation available.

On the present occasion the Institution expected to have had the pleasure of listening to a paper by Vice-Admiral Sir George Goodwin, the Engineer-in-Chief of the Navy. Sir George had written that he had certain work in hand which he would like to complete before submitting his paper. He offered to deliver it that evening in a somewhat mutilated form, if the Council preferred that he should keep his engagement, but the Council felt the paper would be most valuable to the Institution if it were presented in the form in which Sir George preferred to give it. The pleasure of listening to Sir George's paper was therefore postponed, probably until the October meeting, as he did not think an opportunity would occur of giving it at an earlier date. Thanks to their good French friend, Captain Lautier, the members would hear on the present occasion a paper by M. de Chambrier, of the

University of Strasbourg, who had carried out some very interesting work in the mines at Pechelbronn in France. Professor Brame would read the paper, which was an English summary of a work which M. de Chambrier had published in France; it would be illustrated with lantern slides, and at the conclusion of the paper a film which the French Government had prepared, of an educational character, giving details of the mining work carried out at Pechelbronn, would be shown. He had much pleasure in welcoming M. Chambrier to the Institution. The present was the first occasion, within his recollection, on which one of their French colleagues had given a paper. The author naturally spoke better French than English, but he had with him his nephew, M. Jacques Chambrier, who would interpret to him the remarks that were made in the course of the discussion, so that M. Chambrier would be able to answer any points that were raised in the discussion.

The following paper was then read by **Professor Brame**:—

Working of Petroleum by means of "Shafts" and "Galleries."

Extract from a pamphlet of about 100 pages, bearing the same title, published in Paris by Dunod, in January, 1921.

By Paul De Chambrier, *Member*,

Chemical Engineer, Diplômé of the "École Polytechnique" of Zurich, Director-General of the Pechelbronn Mines, Appointed Assistant Professor for a series of Lectures at the University of Strasbourg, Member of the Institution of Petroleum Technologists.

I. Introduction.

The sources of petroleum cannot be compared with the sources of mineral water, as the first-mentioned does not circulate in the earth like water, but is brought to the surface by gas pressure.

If crude oil were found in the earth in large accumulations, underground lakes, pockets or caverns, its extraction by pumps would be very easy and give an excellent yield; but this is not the case, as petroleum has been absorbed by porous layers from which it is extracted with difficulty.

The process of working by boring is rudimentary. It consists in drilling holes a few centimetres in diameter in the petroliferous rocks and extracting, by pumps, the liquid which gathers in these small wells. The resistance offered to the flow of a viscous liquid in a porous rock is so great that only a small fraction of the oil in the beds reaches

Shaft No. 1.

Shaft No. 2.

the pumps, and when the pressure of gas diminishes, the oil ceases to flow.

For every cubic metre of oil extracted from the earth, a volume of gas at least ten times greater may be reckoned, and in that circumstance, it might be dangerous, if not impossible, to exploit crude petroleum by driving "galleries" into the earth as is done in mining.

At Pechelbronn, acting on the advice of the author, an attempt was made in 1916 by the Company to whom the grant had been conceded, the Deutsche Petroleum-Aktiengesellschaft, to drive "galleries" into a bed already exhausted by borings. The result of this bold attempt has surpassed all expectations. It is therefore deemed advisable to draw the attention of petroleum technologists to this new method of extraction, which is based on the following data :—

(*a*) A bed can only be reached by driving "galleries" after oil has already been struck, and the bed exhausted by borings. The presence of gas under strong pressure would render all underground working both difficult and dangerous.

(*b*) The quantity of oil remaining in the bed after exhaustion by boring is still so large that it is a waste of this raw material not to endeavour to extract it by employing more modern and improved methods.

(*c*) This remaining oil may be obtained by draining the bed by means of "shafts" and "galleries." In a gallery of a 4 to 5 sq. m. section the gas escapes slowly and regularly, not bursting forth as is usual in a boring, so that in this manner it is possible to reach the beds, although it is necessary to take certain precautions.

(*d*) After draining by means of "galleries," it is possible, by the extraction and washing of the sand, to obtain the final remnant of the oil. However, this last process has not yet been quite perfected.

II. History.

There exist in Alsace, at Pechelbronn, bituminous sands reaching up to the surface, containing a thick greasy substance free from petroleum spirit and gas. These beds of viscous grease are met with to a depth of 50 metres; therefore, as their working by "mine shafts" and "galleries" did not present any great danger, underground work was started in 1735 by French miners and was carried on uninterruptedly until 1888.

At a depth exceeding 50 metres the "grease" becomes by degrees of a lighter consistency and is accompanied by free gas.

With the somewhat rudimentary methods in vogue of working

mines in the nineteenth century, the underground working became dangerous and costly and was discontinued in 1888.

Indeed, the said beds contained from 3 to 5 per cent in weight of oil, and it was necessary, in order to obtain the grease, to extract the sand and wash it with boiling water.

Furthermore in 1882, borings driven down to 150 metres brought about the discovery of spouting springs, followed by a light oil mixed with gas, and it is largely owing to this fact that the underground working was abandoned some years later.

In 1897, experiments in the saturation of sand, made by the author of this pamphlet, proved that the beds of light crude oil of Pechelbronn retained, through adherence to the sand, the greater part of the oil with which they were saturated, and only allowed the escape of a very small portion of their contents. The conviction was then borne in upon him that it would be necessary later on to apply the system of "underground working" to deep-seated beds, if ever the price of crude oil justified the expenses incurred; such happened to be the case during the war. Experiments in saturation were again undertaken, and it was estimated that by means of underground working two and a half times more oil could be obtained from the earth than by boring. In fact, the said beds of light crude oil contained 13 per cent of oil against 3 to 6 per cent as contained in the beds previously worked. In a report made in December, 1915, the author arrived at the following conclusions:—

(1) In the layers of sand worked by borings, there would remain at least 200 litres of oil per cubic metre of sand, of which part would flow away oozing out naturally and the other would be only obtainable by means of washing with hot water.

(2) Working by "shafts" and "galleries" would give at least 2·5 times more oil than the quantity obtained by borings situated in the confines of the area to be worked.

(3) This method of extraction will furnish the data necessary for estimating the quantities of crude petroleum yet to be won in a district already exhausted by borings. Such an estimate will be analogous to that undertaken for indicating the stock in reserve of a coal mine in course of working.

(4) On this method of working the future of the mines at Pechelbronn will depend, and should the sinking of the "shafts" bring about the result anticipated, their success will be assured for at least one hundred years.

Following this report, a credit of one million marks was granted

early in 1916, the work of sinking the first shaft put in hand soon after, and was finished in April, 1917.

III. Calculation of Crude Oil Contained in a Bed.

1. *American Estimate.*—The question of the porosity and saturation of petroliferous sands, as likewise of all rocks capable of absorbing crude oil, has been carefully studied in England and America.

Mr. Beeby Thompson * gives several examples of sands of an average porosity of from 20 to 30 per cent by volume, but as they still contain gas and are not entirely saturated with oil throughout the whole thickness of the bed, he reckons that their real saturation in point of volume does not reach more than from 10 to 15 per cent. American geologists have also adopted these figures.

Mr. Dorsey Hager † who reckons a practical porosity of 13·5 per cent by volume, arrives at the conclusion that in assessing the petroleum fields of the United States as one "single surface," a layer of sand 2 feet deep would suffice to take in the whole of the petroleum already extracted as well as that which still remains.

Like the American Geological Department, he admits that a boring drains on an average 242·76 ares (6 acres) of petroleum land, and from this reckons the whole of the petroleum producing surface of the United States by multiplying the latter figure by the 329,186 borings made from 1857 to the beginning of 1915. In this manner he obtains a surface of 8093 millions of square metres (2 million acres).

	Millions of cubic metres.	Millions of barrels.
Moreover, these 329,186 borings have yielded ..	530·4	3300
The future production of the wells, still productive in 1914, is estimated at	222·6	1400
Total	753·0	4700

that is about 93 litres per square metre, or 2350 barrels per acre.

The normal thickness of the beds in North America ranges from 8 m. (25 ft.) to 17 m. (55 ft.), without including the beds in California, where it varies between 66 and 99 m. (between 200 and 300 ft.). Allowing for an average height of 9 m. only, the estimate computed on this basis gives a far lower figure than is in fact the case.

* A. Beeby Thompson. *Oil Field Development and Petroleum Mining.* London, 1916. Crosby Lockwood. Chap. III.

† *Practical Oil Geology.* New York, 1919. McGraw-Hill. Page 151.

A 9 m. layer of sand saturated with 13·5 per cent of oil would contain

$$\frac{9\times 13{\cdot}5}{100}=1215 \text{ litres per sq. metre}$$

against .. .. .. 93 litres per sq. metre: yield of the borings as calculated above.

It appears from these figures:—

(*a*) that the yield resulting from exploitation by boring would only work out at $\frac{93\times 100}{1215}=7{\cdot}6$ per cent.

This figure corresponds pretty nearly to Mr. Beeby Thompson's data, the latter reckoning that one-fifth or one-tenth only of the oil contained in a bed is obtainable by the process of boring;

(*b*) that 1 cubic metre of sand would, by the boring process, only supply $\frac{\text{litres per sq. m.}}{\text{thickness allowed for}}=\frac{93}{9}=10{\cdot}3$ litres.

These figures give some idea of the importance of the reserve stock of oil still remaining unexploited in the American strata.

2. *Experiments made at Pechelbronn.*—From the experiments relative to absorption and drainage of the sand, made at Pechelbronn, taking into consideration the real compression in the beds, the following conclusions have been arrived at, and have been verified by analysis of samples of the sands taken from the mine:—

From one ton of bituminous sand they obtain at Pechelbronn:

By "borings"	20 kgs.	or 16·67%
By "shafts and galleries"	52 „	„ 43·33%
So that the oil still adhering to the sand is ..	48 „	„ 40·00%
Original saturation	120 kgs.	100·00%

. Moreover, the results of the underground working show that by the drainage of the beds by means of "mine shafts," 100 litres of oil are obtainable per cubic metre of sand, that is a yield ten times greater than that obtainable by means of the American borings above referred to.

It is well to note that the porous districts of Pechelbronn being composed of relatively pure sand, cannot be compared with certain American beds composed of sandstone more or less cemented by carbonate of lime.

3. *Calculation based on Results obtained from Mining Operations.*—

Front of Gallery.

From a series of observations and deductions too lengthy to enumerate here, the author * has been able to formulate a series of relations between the following data :—

H. Thickness in metres of the petroliferous bed ;

h. Average thickness of the portion of the bed still saturated with oil after working by boring ;

W. Volume per cent of oil of "H," that is the average volume estimated for the whole of the bed ;

w. Volume per cent of oil of "h," that is the part of the stratum saturated ;

v. Volume per cent of oil of the part of the stratum not saturated "h^1" ;

s. Coefficient of "oozing," giving the total of the oil possible to be obtained by underground drainage.

Among the formulæ set out, two of the most interesting are the following :—

$$h = \frac{H\ (W - v)}{w - v}$$

$$s = \frac{h\ (w - v)}{100\ H}$$

The value of "W" can be ascertained by taking little cores throughout the whole thickness of the petroliferous stratum by means of a special diamond-boring device. The value of "w" and "v" would then be determined by analysis of the sand extracted from the mine.

It is therefore possible, given these data, to estimate the reserves of oil still existing in a bed exhausted by boring, and although these estimations can only be very approximate, they will nevertheless allow of very important computations being made. Thus, the theoretical thickness "h" of the saturated stratum, supposed to be horizontal and already exhausted by borings, may be estimated for Pechelbronn at 50 per cent at least of the thickness of the bed.

In the same way, these estimations give for "s," coefficient of total "oozing" of an underground drainage, an approximate value of 0·09, which is equivalent to saying that, given the volume of a bed, one can directly find out the quantity of oil "oozings" it is capable of producing.

Example : A bed of sand, volume 100,000 cubic metres already

* Paul de Chambrier. *Exploitation du Pétrole par Puits et Galeries*, Dunod. Paris, 1921.

exhausted by borings, will yield, at Pechelbronn, as a result of underground draining:

	Cubic m.
"Oil oozings" (100,000 × 0·09)	9,000
Moreover, from observations made in the mining works, it has been shown that the quantities of crude oil still existing in a bed after drainage by "galleries" are nearly equal to those obtained from "oozings"; consequently, the quantity of oil still adhering to the sand will be about	9,000
Total ..	18,000

IV. "Oozing" Theory.

The degree of mobility of the crude oil in the earth is one of the most important questions to be studied in connection with production by "borings" or by "shafts and galleries." The entire theory of anticlinals rests upon the power which the oil possesses of rising in domes, and of permitting water to accumulate in the synclinals. By reason of the pressure exerted by the gas, with which they are saturated, the natural hydrocarbons gush forth like a fountain from the depth where they are hidden up to the surface of the earth; or else they are pushed towards the borings which permit their exploitation; or until they emerge from the rocks, thus giving visible signs: "seepages."

If we were to take as a simile an accumulation of water underground, in a state of absolute repose, situated in a gravel formation, one can have no doubt that its level will be regular, apart from any capillary action the effect of which is to moisten the subjacent rocks. In like manner one may adopt the theory that in a bituminous bed there exist two distinct layers, one of gas and the other of oil; but in our opinion it is somewhat otherwise, the gas being dissolved in the petroleum, and the greater the pressure to which it is subjected, the greater will be the quantity of gas.

It is evident that all of the gas is not dissolved in the oil contained in the bed, since the porous layers are not always entirely saturated with petroleum and the surplus quantity of gas can thus collect in the higher levels.

Considerable quantities, nevertheless, remain in solution, and according to recent observations made at Pechelbronn there may be reckoned per cubic metre of oil: in the case of a "gusher" 10 cubic metres of gas, and for a freshly installed "pumping plant" 5 cubic metres. The proportion is far greater in countries where there is a big production.

We are, however, inclined to think that the undissolved surplus quantity remains nevertheless suspended in the oil, in which it has been formed by slow chemical decomposition, and is prevented from freeing itself by reason of the resistance offered in its passage by the compressed sand, and because the density of the highly compressed gas differs comparatively little from that of the petroleum surrounding it. As soon as the conditions of pressure are modified, it is quite different. A boring on entering a bed causes an ebullition of the gas in solution or in suspension in the oil. Owing to the force of expansion the gas is conveyed in all directions, and the only means of escape offered is the forcing up of the petroleum with which the sand is saturated, and which separates it from the lower orifice of the boring.

Volatilisation of the light hydrocarbons only takes place in the immediate vicinity of the boring. The gradual decrease in the pressure which brought about this ebullition, spreads little by little till it reaches the most distant parts of the bed. As the pressure diminishes, gas in increasing quantities is continuously given off. From each drop of oil microscopic bubbles of gas escape; these act as air pistons owing to the fact that their diameter increases as the pressure becomes less; uniting together, they pursue their way, displacing at the same time the surrounding oil; the whole of this fluid mass is thus set in motion, and the movement continues throughout the period during which boring is being carried on. However, it tends to slow down as the production of the springs decreases. At length there comes a time when the extraction of the oil by pumps is not sufficient to cover working expenses and the bed is abandoned.

Thus the final result achieved by the activity of the gas has not been to bring the oil close to the borings as was the case in the beginning when the stratum of sand was still almost entirely saturated with oil; but rather that of preventing the petroleum from accumulating in the lower reaches of the bed. Indeed, the bubbles of gas endeavour to rise vertically in order to concentrate in the higher parts where the oil is in smaller quantities.

In other words, as soon as the bed is no longer completely saturated, the gas will follow the line of the least resistance towards the opening of the boring, by rising above the oil level and then by flowing along the roof of the strata of petroleum sand where the oil no longer opposes a resistance to its passage. This continuous upward movement of the gas, the globules of which are constantly being renewed, tends to maintain the petroleum, through the exertion of an upward pressure, in a state of suspension in the porous rock, and thus prevents its normal flow. To this is added the effect of the capillary

action of the porous strata, which by its inherent force alone retains the large quantities of hydrocarbons which we have called adherent oil.

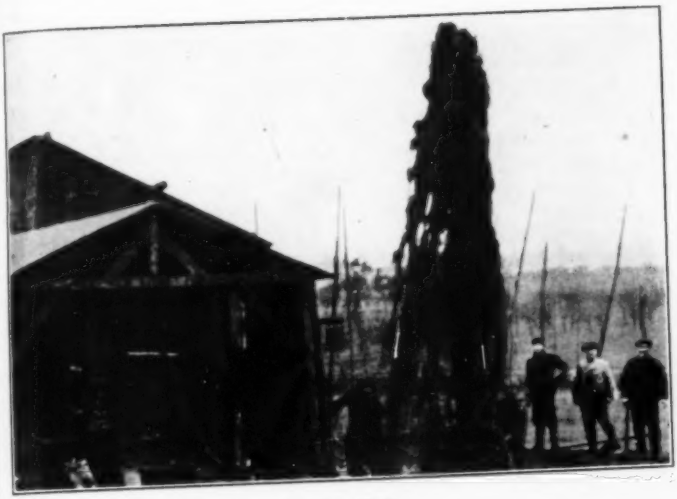
At the time of the abandonment of the exploitation, a state of equilibrium is established throughout the compressed sand of the bed. The viscous oil is distributed among the grains of sand in the form of isolated drops separated from each other by bubbles of gas in a state of immobility, the superficial tension of which forms an impediment to the free flow of the liquid. The reduced pressure of the gas no longer allows of its circulation in the minute channels of the bed ; the oil also can no longer by its own weight succeed in overcoming the resistance of the friction in the capillary openings of the sand, these being obstructed by gaseous globules.

In this manner considerable quantities of oil become unworkable, not having been able while the work was in operation to reach a far distant boring, a boring which Mr. de Launay has so neatly likened to the prick of a needle.*

What will happen if the bed is opened up by "drainage galleries"? Both the fluids mixed with gas and the oils themselves will flow freely. The former will preferably follow a horizontal line towards the galleries, thus allowing the drops of oil to collect. The hydrocarbons will again become active, because the state of equilibrium will have been destroyed. A state of constant pressure upon the oils will soon succeed that of a gradual depression, the constantly renewed escapes of gas no longer recur.

The liquids having no longer this obstacle to overcome, flow slowly through the lower strata until they join the current which is flowing above the floor of the strata, and which very slowly carries the oil unto the "drainage system" formed by the galleries ; so, contrary to what happened when there was no free communication between the oil deposit and the air, the final departure of the gas facilitates the downward flow of the petroleum. The liquid and gaseous fluids continue separately their parallel flow in the direction of the galleries, but the methane and petrol vapours, pressed in between the roof and the petroliferous formation, still bring to bear on the latter a certain amount of vertical pressure. To this vertical force may be added the hydrostatic pressure of the oil which is also endeavouring to make its way towards the front of the cutting. The resultant of these forces acting on the current of oil is shown under the form of a trajectory on the vertical plan traced in accordance with the axis of a gallery.

* "Le Sel et le Pétrole alsacien." *L'Echo des Mines et de la Métallurgie*, 23 Novembre 1919. Page 673. ("Alsatian Salt and Petroleum.")



Flowing Well.

General view of the Pechelbronn Refinery.

An interesting point to be noted concerning the "oozing" theory which we have just formulated, is the curious rôle played by the gas. After having been the motor which caused the oil to gush out fountain-like from the depths of the earth, it is the gas which, at a given moment, hinders its flow. From this we may deduct that by reason of the loss of gas, the petroleum can only flow extremely slowly from the sand which is more or less cemented by an admixture of clay, marl, or carbonate of lime.

Its viscosity alone would suffice to demonstrate this, for it may attain to that of spindle oil or even to that of machine oil (that is, 2° to 6° Viscosity Engler) at a temperature of 50° C. This resistance of the sand may be likened to that of a filter clogged up with colloidal matter which only allows the egress of the liquid drop by drop.

V. Results of the Subterranean Exploitation at Pechelbronn.

The method of exploitation by means of "shafts" and "galleries" is employed in a drainage of petroliferous strata. One does not proceed to work the whole of the bed as in the case of a coal mine. What is required is to drive "galleries" sufficiently distant from each other to ensure the natural flow of the oil.

The attack on the rock, which was formerly made by the miner with his pickaxe, has been recently replaced by drilling with compressed air. This method possesses the great advantage of avoiding the production of sparks and augmenting the work achieved by the miner.

The progress per day is from 60 to 75 centimetres, including all propping and clearing-away work.

In appearance the petroliferous sand is a compact brown mass which seems almost dry, but is in fact very oily, as is easily demonstrated by touching it. It is principally at the lower portion of the layer that oil may be seen oozing out slowly, giving off at the same time almost imperceptible bubbles of gas.

The oil contained in the sand is on an average as follows :—

	Volume per cent.	Weight per cent.
Oozing layers	26·6	12·0
Fatty non-oozing layers	17·0	8·5
Layers exhausted by prolonged drainage ..	9·3	4·8

At the Chief Mining Works at Pechelbronn the length of the "galleries" cut from the beginning of 1917 to the 1st December, 1920, is 5049 metres. These galleries have produced 58,000 cubic metres of crude oil, which allows for each progressive metre an average production of crude oil "oozings" of 11·48 cubic metres.

It may be reckoned that one metre of a gallery of a 4·5 to 5 square metres section drains the oil from 100 to 125 cubic metres of sand, or that in the Pechelbronn bed the depth of which is, on an average, 2 m. 50, one metre forward drains a surface of from 40 to 50 square metres.

In the radius of action of the galleries of the principal works, there were formerly four borings worked by pumps, which had produced in ten years a total of 21,000 tons of crude oil of an average density of 0·880. In three and a half years the "galleries" of this district have furnished 51,080 tons of oil "oozings," that is, 2·43 times more than the borings. This method of working is therefore very remunerative, but certain precautions, which would take up too much time to discuss here, would be necessary.*

It still remains to be ascertained if this method can compete with working by means of borings. It is difficult to reply to this question and to give exact figures, for the industry is still too much in its infancy and has had from the very commencement to combat inherent difficulties, as is usual with every fresh industrial scheme.

We may make an approximate comparison in calculating first the quantity of oil that might be extracted by "shafts" and "galleries" from a somewhat *shallow lying* † bed previously exhausted by boring. Then the endeavour may be made to find out how many borings would have to be made in *new districts* to obtain an equivalent yield of oil.

We will choose, for example, an unfavourable case, that of a bed the working of which would be completed in five years by "drainage," after having driven "galleries" in to the extent of 15,000 metres. On the other hand we will admit that, the works being only carried on in the richest parts of the bed, an average production will be maintained of 10 tons per metre. Working for five years these "galleries" will produce 150,000 tons of oil "oozings."

In spite of the richness of the American oil fields, a boring exploited during ten to fifteen years only attains on an average a total production of about 1300 tons. It would therefore be necessary to bore $150{,}000 \div 1300 = 115{\cdot}4$, that is 116 productive borings in new districts, in order to obtain a quantity of oil equal to that produced by the underground working of abandoned oilfields. Moreover, under the most favourable circumstances two borings must be reckoned for each productive well, which brings the total up to 232.

The expenses necessitated by all this work of research, and the cost

* R. Courau, *Technique des Pétroles*. Paris, 1921. Chez Gaston Doin; P. de Chambrier, *Exploitation par Puits et Galeries*. Paris, 1921. Chez Dunod.

† The depth of the shafts (*puits*) at Pechelbronn is from 150 to 250 m.

of working about a hundred pumping installations carried on during an average period of fifteen years, would not be less than those of an "underground working." The same may be said with regard to the capital to be employed for the purchase of boring and extraction plant, including casing and tubing.

VI. Conclusions.

The extraction of "crude oil" by means of "mining galleries" offers the following advantages :—

1. It allows of obtaining quantities of petroleum two to five times greater than those already produced from the same bed by the boring process.

2. It increases at the same rate of proportion the value of a grant of land, permitting at the same time an estimation being made, which, if not quite accurate, gives a very fair estimate of the reserves of oil still contained in the bed.

3. From an economic point of view, to countries whose petroliferous beds seem to have reached the point of exhaustion it opens up a vista of new and encouraging prospects for the future.

4. From a scientific point of view it is destined to solve a number of questions on points hitherto obscure with reference to the origin of crude oil, its migration, its concentration in the earth, the action of petroleum gases and the stratification of porous rocks.

5. This new industry has had its inception at a favourable moment, petroleum and its derivatives being more indispensable than ever. It will therefore be able to overcome all initial difficulties and, when understood, to keep its footing.

6. Each succeeding year the scarcity of fuel becomes more acute. The question has therefore been raised whether the supply of oil could not be made to cover, to a certain degree, the growing deficit of the coal mines.

To do so there would have to be a material increase in the world production of oil. This seems attainable by means of a more rational working of the beds. A first attempt in this direction has been made at the Pechelbronn mines. Let us hope that the example may not be in vain.

DISCUSSION.

The President said it afforded him the greatest pleasure to propose a very hearty vote of thanks to the author for a paper which he could only describe as extremely fascinating. There were so many things which their French friends did which got hold of the imagination. The process of squeezing the sponge, so to speak, which the author had described, was one that in some form or other might have to be adopted as the oil-fields of the world got a little nearer to a state of exhaustion. He had much pleasure in coupling Professor Brame's name with the vote of thanks for his kindness in reading the paper.

Mr. Cunningham Craig, in opening the discussion, thought the Institution was to be congratulated on having heard a very interesting and important paper—important not only because it described the very successful practical working of a method which was, comparatively speaking, new, but because it made those concerned think a good deal of the way in which oil occurred in Nature and how it was extracted, in fact, what happened at the bottom of a well. Those were subjects which he did not think technologists had thought about quite enough. Pechelbronn was rather a special case. The oil sands were fairly well inspissated, and they did not appear, from what was said in the paper, to be invaded much by water. The extraction of oil from an oil sand by drilling was put, perhaps, at a rather low percentage. In most fields in which there was a distinct structure, an anticline or dome, water followed the oil as quickly as it was taken out, and he thought a rather better percentage of extraction than that given in the paper was obtained. He had been very much interested in the work at Pechelbronn, and for some months he had been studying, in the publications made by the author, the progress of the work there. He was specially interested in the subject, because he had been down two petroleum mines in Moldavia. They were not very deep; they were inclines driven down across the strike of strata which were dipping very steeply and were sharply folded in hilly ground. The mines had not proceeded very far. He went down to the face of one of them quite comfortably, and was shown exactly where the oil was expected to be struck in another 30′ or 40′. In the second one he went down an incline also, with several other people. About half-way down they entered gas, which was so strong that they could not breathe, and they had to come out. No ventilating arrangements had been made at that time, but he believed since then ventilating arrangements had been supplied. Both the galleries had cut oil sand, and oil was already trickling into them. It seemed to him that in a case such as that there was a very good

chance of extracting oil cheaply. The ground was hilly; the strata were dipping very steeply, and sometimes vertically, and it was only necessary to start in any fairly low ground, drive an adit to the oil sand, and cut along it, and all the oil sand above that level must naturally drain by the force of gravity—helped, no doubt, by the gas—into the adit, and so it could be pumped to the surface. In such countries as Moldavia, where it was very difficult to obtain plant owing to the difficulties of transport, that method could not fail to be successful if it was carefully managed and the gas did not become too strong for the miners. There were other parts of the world in which he would very much like to see the same method employed; for instance, in Ecuador, where oil was won by digging little pits through the beach deposit into an impregnated oceanic formation. In that case the amount of oil collected was in direct proportion to the surface of the rock exposed, but allowing the oil to collect in those pits allowed the oil to inspissate. It seemed to him that, by driving galleries horizontally instead of digging a pit every few yards, the oil could be extracted more economically and with less loss of the light oil. There was also the case of the tar sands of Athabasca. That was almost an ideal place to try the method, because the sands there were highly inspissated. They still contained a good deal of oil, and they could be tunnelled by adits at the very base of the formation. He therefore thought the method had very good prospects, but it could not be used everywhere. He would be very sorry to see it tried in some of the oil-fields with which he was acquainted, even after the production of the wells had fallen off. But, taking each case upon its merits, he thought there was a number of places where it could be employed at once with very good results. It seemed to him that every petroleum technologist who was interested in the physical facts with regard to oil beneath the surface ought to study the mines at Pechelbronn. The ordinary work of drilling for oil had been described as mining, although it is not the right term to use, but at Pechelbronn there was a case of actual mining for oil, and the mining engineer could actually come into his own in connection with petroleum. He had no doubt that the cases would be multiplied as the method became better known, and he was sure the Institution was greatly indebted to the author for having put the subject before it in such an eminently practical and complete manner.

Sir John Cadman said he believed the present was the first occasion upon which a Frenchman had read a paper before the Institution, and the members were to be congratulated that the paper had been read by such a distinguished French technologist. The paper was a very practical one on a most interesting and important subject. He was sorry that Sir George Beilby was not present, because he believed that

some thirty years ago Sir George was responsible for the design of the plant which had been shown on the screen that evening. No doubt their Scotch friends would recognize the Scottish practice, which could be seen in the general equipment. It might interest the meeting if he referred to his own impressions of a visit he paid to Pechelbronn just after the Armistice. Petroleum mining at Pechelbronn was indeed a special case; the area did not resemble an oil-field, having its wells spotted about in a beautiful agricultural country. Crops could be seen growing almost within a foot or two of an electrically pumped well. With regard to the mining part of the subject, his impressions at the time were that the Germans had certainly been in need of oil. To have to mine and to extract oil sand under the conditions described, and to wash out oil by means of hot water, were processes which, under ordinary commercial conditions, did not appear to be remunerative. It had been very interesting to hear what the author had said about that matter. The undertaking was young, so far as the latest phase of the development was concerned, although the old grease period dated back for some considerable time, as the author had indicated. Underground the conditions were certainly alarming when compared with coal mining conditions in this country. The risks of explosion and fire were indeed great. At certain places in the mine there were, if he remembered rightly, chambers with iron doors, and a notice on the door saying: "Step inside in case of an explosion, and close the door." Mining under those conditions was very perilous, and he doubted very much whether it would be remunerative under normal trade conditions. He understood that, at the time the method described by the author was reintroduced, it was done at the point of the bayonet; and at the time he was there a strike was in progress, and the management rather feared that the cost of production in mining alone would lead to considerable financial difficulties. He would like the author to enlighten them a little on the economic side of the question, because, when all was said and done, it was a matter of cost of production, even with an oil of such quality. The author had given a most interesting and descriptive paper on an entirely new phase of petroleum mining, but he did not think the author had said quite enough about what was really the important part of the subject, namely, the process of washing the oil from the sand. If the author could see his way to give further information on that point it would be of the greatest use. It was not a simple matter, although it could be easily understood. Galleries were driven and the oil was allowed to trickle down in drains to sumps from which it could be pumped; but to use the material that had been extracted, break it up and put it into the chambers in which hot water was flowing, and then to extract the oil, was a section of the subject

about which little was known. It would be of the greatest interest if the author could state whether that part of the process had become a success. So far as he knew, considerable difficulty was being experienced in setting the plant in motion. Could the author state whether the plant was working continuously and whether they were able to extract the oil from all the material that was mined.

Dr. Ormandy said that, having put in a few months' work at one of the very fiery mines in Lancashire, when he read the paper his admiration for the French miner grew very considerably, and he came to the conclusion that it was a very good thing that in working the various adits and dividing the bed into sections it was not necessary to do what was done in the collieries, namely, to extract as much of the material as possible, realizing that it was better to run the process with a view to letting as much as possible seep out into the galleries rather than to go to the extreme of extracting the bulk of the material. The people of this country had, of recent years, learned to a considerable extent what it meant to be dependent upon a class of people, colliers, for a very important raw product of industry, and it was rather fearsome to think that the alternative fuel, oil, might at some time or other be dependent upon the same class of people. Nevertheless it was very deplorable to think that in the ordinary method of obtaining oil such a small proportion was obtained of that which was really present; and in view of the growing demand for oil, and in view of the certainty that there must be, in many of the oil-fields, conditions which are at least as fitting, or perhaps more fitting, than those at Pechelbronn, it was a most important thing that the subject should have been brought before the notice of the members. There were certain points raised in the paper which he did not quite understand. There was the statement, for instance, that in order to get over the danger of fire induced by working with a pick, pneumatic tools were used. He knew from experience that quite handsome sort of sparks could be obtained from a coal containing pyrites with a pneumatic boring drill, but he presumed the current of air from the exhaust of the tool was sufficient to dilute the gases below the ignition temperature. For the sake of the poor people who worked below, it was an exceedingly good thing that the temperature of ignition, both of methane and petrol, was comparatively high, and if ever carbon disulphide had to be mined they would have a worse time still. It was quite obvious that the proximity of the adits must depend on the nature of the strata from which the seepage was required. The amount which would come out depended on the viscosity of the oil as well as on the nature of the strata in which the oil was contained, because if the sand was exceedingly fine it was quite obvious that by capillarity a great deal more would be held back than if

the sand was coarse. Fine precipitates would retain up to 40 % of water under a pressure of 90 or 100 lb. to the square inch, whereas a coarse precipitate would retain only 8 or 9 lb. to the square inch. If to that was added the variation in the viscosity of the oil, it was quite clear that the greatest care must be exercised in drawing deductions from one special case to the general case. Nevertheless, it was quite obvious from the figures that were given in the paper that it would be possible to carry out comparatively few experiments and from those draw deductions which would enable one to apply the process to quite other conditions. It was clear that the author could not give much more in the time than he had done, but he had certainly left many very interesting points untouched upon: for instance, how the headings were bored, whether timbering was used, and whether tubbing was used, or whether the header was driven and followed up by metallic tubbing or concrete. There were so many ways of driving that it would be interesting to know what method was employed and what method the author would recommend in cases where the material in which the oil was contained was of a soft nature. Clearly at great depth the process was quite impossible. In any case it did not depend entirely on the nature of the strata down below, but on the cost of putting the shaft down. A 500-yard shaft to get down to the bed might cost £10,000 or £20,000, but there were lots of known cases where it had cost £400,000 to put down a shaft. Those were points which required further elucidation.

The Author, in reply, spoke in French, but his remarks were interpreted into English by his nephew, M. Jacques de Chambrier. He said he was exceedingly grateful for the manner in which the members had received his paper. The working of petroleum by means of shafts and galleries was a competitive method to the working of bituminous shale. He was much gratified at the applause with which the remark was greeted that the system of using shafts and galleries was a competitive one to the exploitation of Scottish shales. That was really English! The working of petroleum owed its success to the working of the bituminous shale. The production of petroleum, paraffin, and oil was due, in the first place, to the working of that shale, and that cleared the way for the petroleum industry. The petroleum industry must indeed be very grateful to the English shale industry for what had been done in that respect. Mr. Cunningham Craig had not criticized the paper, and the remarks he had made were therefore easy to answer. Mr. Cunningham Craig said he thought petroleum could be worked at many places in the world by means of shafts and galleries. In his own opinion that was quite true, but many precautions were necessary. The industry was a young one, which must be sustained by all those

interested in it, and Mr. Cunningham Craig, in particular, could be of the greatest use in the development of that industry. Sir John Cadman, who had spoken from the economic point of view, was anxious to know if all the oil sand could be washed. It was, of course, only possible for him to say what he knew. Sands analogous to those at Pechelbronn could be washed, but it would not be so easy to wash sands which were cemented. The washing of sands with boiling water was a question of cost. They could be washed immediately if cost did not come into consideration. Everything depended on the value of the crude oil. The development of the system of shafts and galleries depended also on the cost of crude oil. If the system were to take the place of deep borings it would probably be too expensive in deep strata and in strata with water. It was therefore prudent to begin the work of shafts and galleries in shallow strata. Dr. Ormandy had asked if the temperature of ignition could be reduced. It could for methane. Methane exploded only when heated to a certain temperature. All workers in coal mines knew the limit of explosion as well as the temperature of explosion, but with the gas of petroleum it was quite different. A spark caused by the pick of a worker could not light the gas in a coal mine, but it could light the gas in petroleum shafts. Therefore the working by means of shafts and galleries was certainly dangerous, and the first thing to do was to learn how to struggle against those dangers. Fire must be avoided, and then explosion did not offer any danger. Without fire there could be no explosion. In order to avoid fires they replaced working with picks by working with hammers under the Flottman system, and since that system had been introduced no sparks had occurred. The beginning of a fire could be very easily extinguished if the workers were cool and were not afraid. The first thing necessary to combat fires was the formation of groups of "Safety Men," who struggled like fiends against fire as soldiers against the enemy. Dr. Ormandy also stated that timbering was a cause of danger. As a matter of fact that danger had been avoided, because in the face of the gallery the timber was replaced by iron tubes. Further in the gallery timber was used, because there was no danger of fire there; it was only at the face of the gallery that any danger of fire existed. By using iron tubes all danger of fire was prevented.

In conclusion, he desired to thank the President, the Committee of the Institution, Professor Brame for his kindness in reading the paper, and the members for their kindness in attending. Professor Brame's task had been a very difficult one, because he had had to explain a paper which he had not written himself. He also desired to thank M. Lautier, who undertook the difficult task of translating technical terms from French into English. Unfortunately he (the author) did

not speak English, but he was pleased to know that Captain Lautier's translation had been thoroughly understood by all the members.

The meeting then terminated.

Contribution from Mr. C. N. BROMEHEAD.

The closest analogy to the workings by galleries at Pechelbronn with which I am acquainted are the occurrences of petroleum in coal-mines in various parts of England. There are many such occurrences on a small scale, and one or two have been of commercial value: the well-known seepage at Riddings Colliery, Derbyshire, where Young first worked, yielded about eight barrels per day for two years and smaller quantities for twenty-six years. At Manvers Main Colliery near Rotherham about 220 barrels were collected during three days and enough to be worth marketing for fourteen years. In every case where such coal-measure oils have been examined, the proportion of high members of the paraffin series is remarkably large, such substances as eicosane ($C_{20}H_{42}$) and pentacontane ($C_{50}H_{102}$) and intermediate paraffins being found. From the description given of the slides showing refineries, etc., at Pechelbronn, the oil there appears to be of similar character, yielding a considerable amount of wax. It would, therefore, be interesting to learn from M. de Chambrier whether there are other similarities between the English and Alsatian occurrences. A study of the former has led one to the conclusion that the former oil is (1) of vegetable origin, (2) indigenous to the coal-measure-shales, or part of them, (3) obtained where a sandstone cuts across the bedding of the shale, either at a fault or in a wash-out, and is consequently fed by seepage of petroleum along the bedding planes of the shale. The Pechelbronn field is situated in a much faulted area, but the rocks are of Mesozoic and Tertiary age. I should much like to know M. de Chambrier's opinion as to the origin of the oil, the rock to which it is indigenous, and the influence of the faulting on its concentration.

Contribution from Mr. WILFRED E. GOODAY.

Had time permitted one could have fired innumerable questions at M. de Chambrier on the subject of his interesting paper. The replies to many of such questions are probably to be found in the author's publication which, I am sure, will be consulted by many of us who were present at the reading of his stimulating extract.

In the application of the advocated methods of exploitation to other fields the main factors, beyond the primary economic considerations, will be the nature of the oil-bearing rocks and the type of oil recoverable.

I think it would add to the value of the data given by M. de Chambrier were he to give an analytical statement of the oil he obtains at the present time.

The system described is no doubt suited to certain shallow fields where extraction of the thicker types of oil is carried on, but it is obvious that there are oils to which it is quite unsuited. The limiting cases would vary according to prevalent economic conditions.

In reference to Mr. Cunningham Craig's hint as to the necessity for further study of underground conditions of oil sands, it is of interest to know what differences (if any) have been observed in the quality of the oils obtained by the respective methods of exploitation, namely, shafts and galleries and well boring.

Although the presence of water in the formations would add considerably to the difficulties of working, it is conceivable that some modification of the "freezing" method of shaft sinking could be employed if it were worth while.

Contribution from Mr. ARTHUR W. EASTLAKE.

I much regret that the limited time allowed for the discussion of M. Paul de Chambrier's most interesting paper did not permit me to ask him on what he based his assertion that, in the United States of America, two borings must be made in order to obtain one productive well.

The following particulars, taken from the official statistics published by the United States Geological Survey, show the ratio between productive and dry holes :—

WELLS DRILLED.

	Oil.	Dry.	Ratio of Oil to Dry.
1917 . .	16,590	4851	3·42 : 1
1918 . .	17,845	5613	3·18 : 1

These figures are exclusive of wells drilled for oil which only produce gas, and which amounted to 1966 in 1917 and 2229 in 1918.

M. Chambrier also states that the average total production of a well for ten to fifteen years is about 1300 tons. According to the statistics mentioned above, the average production per well in the United States in 1917 was 1701 barrels (approximately 230 tons) and in 1918, 1750 barrels (approximately 240 tons).

Contribution from Mr. I. A. STIGAND.

The instructive and original paper by M. Chambrier suggests many questions—particularly in connection with porosity, the mode of occurrence of the oil and gas in the reservoirs, and conditions of flow. Such are of course primarily concerned with questions of capillarity, frictional resistance and viscosity. While the consideration of the behaviour of and the rôle played by the gas associated with the oil is important—more especially so in view of the problems connected with the gravitational separation of oil from water (for it is found experimentally that oil separates with difficulty from water in sands other than those of extremely coarse grade, capillary interference not being overcome, but that separation readily takes place on passing air through the mixture), not much account is taken of the important part played by water, either in cases of the existence of hydraulic pressure, or in virtue of capillary power and selective segregation—in the matter of the flow and recovery of the oil, as well as in that of separation and concentration. In many fields the water gradually rises up dip, taking the place of the oil—on the exhaustion of the latter—so that in this way most of the petroliferous bed may become drained by the water. In the case of ideal structural conditions with the presence of hydraulic pressure in the reservoirs and the gradual displacement of the oil by water, it is difficult to conceive better conditions for the recovery of the oil than those obtainable by borings, when such have been favourably located.

The mining and recovery of oil in pits and galleries would seem to be most applicable to cases where the strata are too disturbed or broken, or the dip too high (as has often previously occurred to the writer) in order to admit of economic exploitation by drilling as in some instances in N. Borneo and Trinidad. In this manner, valuable oils could often be recovered, when unremunerative quantities only can be expected in borings, or where the drilling is too speculative.

In regard to working the Athabasca bituminous (" Tar ") sands by this means—as was suggested—I doubt whether any appreciable flow or " oozings " from the beds could thus be obtained—even if penetrated at considerable depth. There would, moreover, be the difficulty connected with the large quantities of natural gas associated with these beds. Exploitation of these deposits would seem to only be practicable by means of destructive distillation.

Contribution from Mr. A. BEEBY THOMPSON.

To M. Chambrier is due not merely the thanks of the Institute but the gratitude of all petroleum technologists for his courage and initia-

tive in putting into practice operations that have often been the subject of consideration by thoughtful operators. All petroleum investigators have long realized that we were obtaining but a small fraction of the oil the beds contained, and numerous have been the schemes projected for obtaining a larger proportion of those contents. M. Chambrier has conclusively proved what was suspected and incidentally given us for the first time in history a glimpse of subterranean oil-field conditions never before disclosed to man.

In Galicia the great ozokerite workings have afforded a means of studying some of the phenomena associated with oil distribution, but at Pechelbronn an actual oil-field can be examined in comfort and at leisure, and the condition of so-called exhausted oil sands can be inspected.

Through the courtesy of M. Chambrier the writer was permitted to descend the workings early this year, and without exaggeration he can affirm that it would be difficult to seek a more fascinating and instructive excursion. Owing to the peculiarly favourable geological conditions and the excellence of the mining operation, little inconvenience is sustained in traversing the galleries and examining the working faces.

Amongst the many interesting phenomena which attracted special attention were the occurrence of non-petroliferous seams and lenticles in the dark-stained oil sands, and the passage of oil along small slip planes or joint cracks. The writer has always inclined to the view that all movements in tight sands are largely influenced by cracks along which oil can more freely move. Often little squirts of oil could be seen issuing from disturbed zones, and it could be well understood how important would be these fissured systems when much gas was present with the oil to cause its expulsion to points or relieved pressure.

It must be acknowledged that the conditions at Pechelbronn are exceptionally favourable for mining. The strata are nearly horizontal, water in objectionable quantities does not exist, and the beds are sufficiently compact to hold up without excessive timbering. A slight dip ensures efficient gravity drainage to low points where the oil can be abstracted, and there are few faults or flexures that throw the oil sands out of level. Nevertheless there are undoubtedly abandoned oil areas known to-day where the process could be introduced if cheap and good miners could be found locally. I am inclined to doubt whether such works could be made to pay in regions where the beds were severely contorted and fractured, as the cost of mining and timbering would be too high and the danger of sudden gas, oil, or water influxes too great. Nor could mining be economically undertaken where the beds were very deep or overlain by water-bearing strata.

Reply by M. PAUL DE CHAMBRIER.

The way in which the Institution of Petroleum Technologists studies a question of the day is such a methodical and systematical one that it ought to be imitated by other countries. The General Commissary of Petroleum in Paris being aware of the importance of this Institution, has long ago sent a delegate to London, Captain Lautier, who besides other missions, has to keep in touch with it. Captain Lautier got this learned Society to study the question of working petroleum by means of shafts and drifts, a method being applied in the French mines of Pechelbronn, and made it the topic of a lecture.

To answer the numerous questions called forth by the lecture in a somewhat complete manner, much writing would be necessary. However, the author's task is a simple one since he has but to refer to the recently issued publications dealing with Pechelbronn, the most important with regard to geology being the work of M. Gignoux and as to the technical point of view, the publications of M. R. Courau and those of the author.*

After the lecture of February 15th, 1921, MM. Paul and Jacques de Chambrier briefly answered the questions put by Mr. Cunningham Craig, Sir John Cadman, and Dr. Ormandy. The author will again allude to these questions after having dealt with the written observations directed to the Institution of Petroleum Technologists.

Mr. Arthur W. Eastlake, universally known for his statistics and works, is perfectly right when he points out two figures which do not seem to him to be correct. The author's point of view is quite a different one; he supposes that in eighteen years (†) to come, the United States will have exhausted their reserves. Then they will have to prospect in new grounds, i.e. as yet unexplored and more or less unknown, or they will have to undertake the working of old beds by means of shafts and galleries. In the first case it would be already advantageous to strike a productive well out of two borings.‡ The

* Gignoux and Hoffmann: "Le Bassin Pétrolifère de Péchelbronn." Extract of the *Bulletin of the Service de la Carte Géologique* d'Alsace et de Lorraine, 46 pp., 3 plans.

P. de Chambrier: *Exploitation du Pétrole par Puits et Galeries.* By Dunod editeur, Paris, 1921, 106 pp., one plan.

R. Courau: *Technique des Pétroles*, at Octave Doin, Paris, 1921. See Chapter II, pp. 149–76.

† *Exploitation du Pétrole par Puits et Galeries*, p. 18.

‡ L. C. Tassart: *Exploitation du Pétrole*, 1908, Paris, at E. Dund. Tassart estimated in 1908 that the dry holes amounted to 60 % in the region of the United States not entirely explored. He assumes that three or five borings (p. 156) are required for a research in a new oil-field.

percentage of dry holes compared to the total number of wells completed in known regions, varies much :—

United States, Total *. . .	1918 . .	21·8 %
" " Appalachian .	1909 . .	26·8 %
" " " .	1918 . .	17·5 %
" " Illinois . .	1909 . .	17·7 %
" " " . .	1918 . .	27·3 %
" " Coastal Texas .	1915 . .	42·5 %
" " Coastal Louisiana .	1917 . .	45·5 %
Alsatia-Pechelbronn . . .	1918 . .	58·8 %
" " . . .	1920 . .	37·6 %

The figure of 1300 tons yield of a productive well in the United States results from a calculation detailed on pages 15 and 100 of M. de Chambrier's pamphlet. It is based on the data given by Mr. Dorsey Hagar on the production of the United States from 1857 to 1915. He admits that this figure may be questionable according to the given specific gravity of crude oil and according to the estimation of the oil quantities that productive wells can still yield.

If we abandon those two uncertain data, we shall see that the 329,186 productive drills have yielded from 1857 to 1915 an average of 1611 cubic metres. On the same basis of calculation one comes to state for the Alsatian drills a total yield of about 1300 to 1400 cubic metres.

The conditions of research and working in the United States are entirely different from those of Alsatia ; for that reason it is difficult to draw a comparison. However, it seems admissible to the author that in countries where certain layers have reached their limit of exhaustion by borings, the underground working may give results, if not superior, at least similar to those of Pechelbronn where the petroliferous sands are rather poor.

The author comes to the question put by Mr. Wilfred Gooday concerning the particulars of crude petroleum extracted from the galleries : This oil is identical to that yielded by borings. The following analysis is that of ordinary crude oil of Pechelbronn † :—

Specific gravity	0·888
Engler viscosity number à— 50° C. .	2·2
Cold test	5° C.
Paraffin wax	4·2 %
Asphaltene	2·3 %

* E. Russel Lloyd : *Petroleum in* 1918. Washington Government Printing Office, 1920. *Mineral Resources of U.S.*, 1918, Part II, pp. 982–3.

† P. de Chambrier : "La Sourcè de Pétrole jaillissante de Pechelbronn "—*Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, Juillet-Août, 1920.

Fractional distillation (% by weight of crude oil).

To 150° C. . .	5·9
150–300° C. . .	27·8
Residues and loss .	66·3 (specific gravity of residue 0·943)
	100·–

The composition of this oil is quite different from that of the grease obtained in the years 1735 to 1866 by washing the sand extracted from shallow layers.*

Specific gravity	0·965–75
Engler viscosity number at 50° C. .	40°–50°

This grease did not contain benzine, and only very little burning oil (kerosene).

In the years 1867 to 1882, a heavy crude oil of 0·940 to 0·950 specific gravity and 15° to 20° viscosity at 50° C. was obtained in the underground workings. It gave from 9 to 12 % by weight of fractions, distilling from 150 to 300° C. At that period the first oozings in the galleries were noticed. The yield of the underground drainage will be more important with crude oils of an average specific gravity than with very viscous oils.

Mr. Cunningham Craig, Mr. I. A. Stigand, and Mr. Beeby Thompson enter all three upon the question of the stratification of the grounds, of their geological and physical structure and of the constitution of water-bearing strata. Only experience will be able to prove if the method of mining works can also be applied in sharply folded and fractured oil layers. The communication made by Mr. Cunningham Craig concerning the visit he paid to the mines of Moldavia is very interesting, as he there had observed grounds very inclined.

However, such an attempt would be venturesome and expensive, if any danger of water invasion existed or if the presence of moving grounds were to be presumed.

These gentlemen, as well as Dr. Ormandy, remarked quite rightly that the conditions at Pechelbronn are favourable for mining work at such a high degree that this method, which is but in its cradle, cannot be generalized to all grounds. A failure would impede the success of this new industry for a long time. It would therefore be a good thing that the first attempt should be made with the utmost prudence, and preferably in those regions where the strata are somewhat similar to the Alsatian ones.

* P. de Chambrier *Historique de Péchelbronn*, at Attinger Frères in Paris, 1919, p 133.

Much time will be required before the technique will eliminate all dangers resulting from fire, gas, and water. Those matters will be elucidated by the collaboration of geologists and mining engineers.

To avoid fire and explosions it is wise to replace compressed air by electrical power in the galleries, a method which is much more expensive. Compressed air can only be used for little motors and is not suited to the driving of exhaust pumps powerful enough to strive against a great influx of water.

Concerning water, Mr. I. A. Stigand points out the fact that it is able to remove oil and to drive it to certain favourable situated wells. It is known that in America the production of certain oil-fields could be increased by injecting great quantities of water into the layer. In the case of sands as dense as those of Pechelbronn it can hardly be admitted that water may find its way through them with the effect of removing completely the oil which they contain. Water may soak in by fissures, passing through little channels along which oil had formerly run or through strata specially porous inserted in the petroliferous sands, but after this infiltration has taken place there will still remain important quantities of oil in the layer.

It is easy to prove it by a laboratory test. Crude oil is introduced into a funnel, filled with dry sand, by the bottom, until it rises on the surface of the sand, then it is left to drip during twenty-four or forty-eight hours. After this last operation the sand still contains 50 to 70 % of the oil with which it has been saturated. Tepid water may then be introduced into the funnel from bottom to top without any important quantities of oil being carried away.

This trial does not represent the conditions of a layer where the sand is very tight; it enables only to show to what extent the capillarity interference of the grains of sand is considerable. The sands drained hitherto by galleries contain but little water. The lowest parts of the incline contain more water than the highest parts of the layer in which gas prevails and where salt crystals can be noticed. A simultaneous evaporation and separation of the water seem to have taken place before the complete settling of the porous strata.

According to the saturation of the layer, to the size of the sand grains, to their state of purity, to the quality of the oil, phenomena of adhesion, of capillarity and absorption, hard to limit, can take place.

The author had inferred from laboratory test that the amount of oil which could flow in the layer towards a well was much inferior to the yield obtained by dripping in the laboratory, consequently the underground working followed by the treatment of the sands with boiling water would make it possible to extract very large quantities of crude oil.

This conjecture was not only confirmed by the underground drainage, but it has been stated that by this method a greater proportion of oil can be obtained than as the one calculated by trials. The author tried to give an explanation of this phenomenon by the behaviour and by the active part of the gas associated with the oil, but he would be happy if more competent persons would try to solve this difficult item, on which the new extracting system is based. The result of this theory is that the washing of sands is not of the same importance than was formerly admitted. Moreover, the veins of clay, often interspersed in the deposits, diminish the quality of the sand extracted from the galleries and add to the difficulty of treatment by boiling water, therefore it had been dropped for the present. However, with regard to the future, the trials of treating the sand are being continued. Oil will surely one day be recovered from the sand by mechanical means cheaper than by destructive distillation of bituminous shales.

In connection with this matter, Mr. Bromehead asks what analogy is existing between the Alsatian crude oil and that of the bituminous coal mines of England where important oozings have been noticed. The analytical statement given above of oil obtained from oozings, will allow to establish a comparison with the English oil. The chemical composition of the Alsatian oils shows much resemblance with those of Pennsylvania, though their proportion in benzine and lamp-oil (kerosene) is a different one. At Pechelbronn bituminous shales have never been observed near petroliferous sands.

As to their origin, M. Gignoux writes in his conclusions*: "With regard to the origin of petroleum, we shall merely remark that our Alsatian basin bears arguments in favour of the sedimentary origin of crude oils and of their connexion to the formations resulting from deposits in lagoon."

Sir J. Cadman went down the shafts of Pechelbronn at an unfavourable moment; it was shortly after the Armistice. The danger of fire and of explosions was then much more important than it is now, the ventilation was insufficient, the work of the miners was unhealthy, and there was, moreover, a tendency to strike. Since that time the situation has entirely altered: the accidents which have happened in August, 1919, led to considerable improvements, confidence has come back among the miners as well as among the owners. The two new shafts, sunk in 1920, are the best proof thereof. The washing plant for the sands was a war instalment, hastily erected, and has not given good results. For the present it can be but a secondary industry, as the oil obtained in that way will be necessarily more expensive than the oil resulting from oozings which is as pure as that yielded by borings. Even its treatment

* *Le Bassin pétrolifère de Péchelbronn.* Work already mentioned, p. 37.

is easier than that of oil obtained by well-borings as it contains much less water and no earthy materials.

When by thorough drainage all the oozing-oil as well as the gas still contained plentifully in the strata will be exhausted, the mine can be worked quite otherwise, and it will no longer be dangerous to fit up electric wires in the galleries. Then the working of sand will have to be started like the working of any other ore. Sand will be washed on the surface or at the bottom with boiling water or treated in any other way to extract the oil it still contains.

At present the main fact is to avoid all causes of fire. The use of the pick machine (puncher) presents a great improvement. Hitherto the sparks observed by Dr. Ormandy in the pyritiferous coal mines have never been noticed in greasy sands.

Dr. Ormandy, in the author's pamphlet dealing with the working of petroleum by means of shafts and galleries, will find the answers to the other questions he put concerning the driving and timbering of galleries. The sinking of shafts to a depth of about 150 to 250 metres does not raise any difficulty at Pechelbronn, where water-bearing strata do not exist.

The cost of sinking shafts and their depth would be but of little importance if, after this first outlay, oil-bearing strata of far greater size than those of Pechelbronn could be drained by galleries rather inexpensive.

The extraction of the oozing-oil out of the mine costs hardly nothing compared with winding of coal. Finally the commercial value of coal is four or five times lower than the value of crude oil.

Mr. GARNER'S Reply to the Discussion on his Paper. (*Journal* 26, *page* 99.)

There seems to be a certain amount of confusion between the terms carbonisation, or resinification of oils and the coke content of oils, although the two terms are quite distinct. Carbonisation is the gradual decomposition of the oil which occurs when an oil is exposed to high temperatures; in this decomposition, the oil gradually darkens in colour owing to the production of resins and eventually asphalt-like materials are deposited. If the process of carbonisation is carried on for a sufficiently long time the asphaltene formed is transformed into coke. The coke content is, however, the amount of coke formed by distilling the oil rapidly in the absence of air. The Conradson test has been used for the last eight or nine years in America for routine deter-

minations of the coke content of lubricating and other oils. The Ramsbottom test, mentioned by Mr. Evans, appears to lack the suitability for routine work of the Conradson test.

As regards the dependence of carbonisation on the character of the hydrocarbons the author carried out some experiments on the action of high temperatures on paraffin wax, and found that practically no asphaltenes were formed, even when a large proportion of the paraffin wax had evaporated away. There is, therefore, a decided difference in the behaviour of saturated hydrocarbons such as are present in paraffin wax and olefines or naphthenes which are present in lubricating oils. The experiments which Mr. Evans proposes to conduct should throw much light on the question of the relative stability of different types of hydrocarbons when subjected to carbonisation at high temperatures.

In reply to Mr. Parnacott's question on dilution, the tendency in America at the present time is to remove the oil from the crank case before it is diluted to such an extent that there is a danger of damage to the engine owing to under-lubrication. The oil removed in this way is then treated by a reclamation process, such as that referred to on page 28, by which carbon, asphaltic materials, and other impurities are filtered off and the heavy ends are removed. The oil recovered in this way is used again. During the war it was the practice in the United States Air Service to remove the oil periodically from the crank case of the engines and treat it in this way. It was found that the recovered oil gave better results in service and fewer difficulties, owing to carbonisation in the cylinders, than the unused oil. Dilution can be minimised by paying special attention to carburetion; as small an amount of fuel as possible should enter the combustion chamber in liquid form as liquid fuel is absorbed by the lubricating oil very rapidly. To avoid this difficulty attention has been paid to the construction of 'hot-spot" manifolds, utilising the heat of the exhaust to vaporise the incoming fuel. Another point which is of assistance in preventing dilution is the maintenance of a sufficiently warm temperature in the water circulating system by thermostatic control, and thereby maintaining the lubricating oil at a higher temperature.

In reference to the point raised by Dr. Lessing in regard to the determination of asphaltenes in petroleum, it should be remembered that the dilution of the oil in so large a volume as twenty volumes of petroleum ether will tend to minimise any solvent effect which the oil itself might have on asphaltenes.

There does not seem to be any advantage gained by carrying out the carbonisation test for forty-five hours at 150° C., when a few hours at 250° C. will give the same results. This point is well illustrated in

the curve presented by Dr. Ormandy and also by the figures given in Tables IX, X, and XI.

There seems to be a good deal of evidence that the lubricating oil which enters the cylinder does enter mainly in the form of spray, aside from the capillary effect mentioned by Dr. Ormandy. In cases of over-lubrication the oil comes out of the exhaust in the form of blue smoke, and it is, therefore, probably present in a finely divided form in the cylinder. Owing to the rapid motion of the piston and the fact that all oils used for the lubrication of internal combustion engines are relatively thin at the temperature of the cylinder walls, it seems highly probable that oil is present in the combustion space as spray. Neglecting the small amount of the oil lost by the breather, the consumption of oil by an engine is dependent on the oil burnt in the explosion stroke or carried out in the exhaust; when the piston rings are loose-fitting or when the slots of the piston rings come together there is a great increase in the consumption of oil in an engine, and this is more readily explained by the oil being present as spray than by the capillary theory. The fact, too, that there are often thick deposits of carbon on the cylinder head, is more readily explained in the same way.

In conclusion I wish to express my thanks to Dr. Ormandy for presenting the paper and for the interesting facts brought out in his reply to the discussion.

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164. ———— Action of Floridin on Unsaturated Compounds. *J. Russ. Phys. Chem. Soc.*, 1915, **47**, 827; *Chem. Abstracts*, 1915, **9**, 3005.

ERRATUM.

In Captain Mangin's paper, "Boring in Palestine," which appeared in Journal 26, Fig. 2 represents the German Rig, and Fig. 3 the Fauck Plant, the legends having been unfortunately interchanged.

The Fifty-fourth General Meeting of the Institution was held at the house of the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday evening, March 15th, 1921, Sir Frederick Black, K.C.B. (President), occupying the Chair.

The President, at the opening of the meeting, announced that a special meeting of the Institution would be held in the rooms of the Institution of Mechanical Engineers at 6.30 p.m. on March 21st, for the purpose of showing the film which has been prepared by the Bureau of Mines in America, in conjunction with one of the American oil companies, giving the history of the oil industry. The Annual General Meeting of the Institution would be held at 12.30 p.m. on March 22nd at the Offices of the Institution, John Street, Adelphi, and the Secretary requested that any alterations in the List of Members should be sent to him at the latest by that date.

The Secretary announced that the following had been elected since the last General Meeting:

As *Members*:—William Fraser, Leonard Bertie Holloway, William Henry Huxley, Harry Howard Johnson, Thomas Landell-Mills, John Lander, Thomas George Madgwick, Lincoln Coslett Rogers, George Sheppard, Alan Carrick Smith, William John Wilson, Hugh F. Wright.

As *Associate Members*:—Owen Colverd, William Dallas, Stanley James Davies, George Samuel Hay, Clifford Hollingsworth, Felix John Hookham, Stanley George Hughes, Ralph Howard Mitchell, Henry Frederick Moon, Samuel William Shepperson, William Alfred Simper, Reginald Gordon Stickland, Claude Moorhouse Stoney, Francis Tipler.

As *Students*:—Ernest Leon Bass, Charles Jackson Calderwood.

As *Associates*:—Arthur McNeill Farquhar, Montague Skitt.

The President, in introducing the author of the paper, Mr. James Kewley, said that a paper by Mr. Kewley had been published in the Proceedings on a previous occasion, but he thought the present was the first time that the author had actually read a paper in person before the Institution. He desired, on behalf of himself and all the members, very cordially to welcome the author as one of the most active Members of the Council, particularly as he was about to refer to a subject about which the members had not heard enough up to the present time.

The following paper was then read:—

The Crude Oils of Borneo.

By J. Kewley, M.A., F.I.C.

The crude petroleums which are found in large quantities in the island of Borneo show considerable variation in type, those from one particular field exhibiting characteristics which differentiate them sharply from most other known crudes. Oils of such peculiar character merit much more scientific investigation than they have yet received. The character of these crudes, which was destined to render them of such particular value, under conditions of modern warfare, and later in the light of recent research on motor fuel efficiency, had, in the early days of the Borneo industry, quite the reverse effect.

It is intended in this paper to give a brief outline of the chemistry of these crudes as far as is at present known, together with some account of their geology, in order to suggest a possible relation between the chemical characters of the oils and their mode of accumulation, a relation which if followed up and supported by future research might help to shed some light on the vexed problem of the origin of crude oils generally. Incidentally a brief outline of the method of working up these crudes into commercial products will be given, indicating how these methods have been modified to meet present day conditions and demands.

The petroleum industry of the East Indies, which has now assumed considerable dimensions, is of comparatively recent growth, dating back, in the case of Borneo, to not earlier than 1897. The production of the Koetei fields, which were first developed, has steadily increased and has been supplemented by that of areas developed at later dates.

Indications of petroleum had long been known in Borneo and the other islands of the East Indian archipelago (Posewitz, *Borneo*, Berlin, 1899).

As far back as 1853 Motley noticed oil occurrences in the island of Labuan. In 1863 Menten found also seepages in the island of Tarakan, on the east coast. In 1866 a very shallow well was drilled in Labuan which gave a small flow of oil for thirteen years at least. Collingwood, in 1867, described a petroleum spring in British North Borneo, and stated that others were known. About 1887 three wells were in existence on the Klias peninsular on the north of Brunei Bay, and these gave oil in very small quantities.

J. H. Menten was certainly the pioneer of the oil industry in Borneo. In 1888 he obtained oil and coal concessions near the mouth of the Mahakam River, which concessions give to-day the most important output. In 1891 he obtained further concessions near Balik Papan,

then a tiny fishing village, now a thriving refinery centre. Further indications are found in the Bolongan area, in West Borneo, Sarawak, and elsewhere (*Engler-Höfer Das Erdöl.*, Vol. II, p. 535).

In 1897 the first well was put down at Sanga Sanga, and oil was found at 58 metres. In August, 1898, the Nederlandsch Indische Industrie en Handel Maatschappij, and about the same period several other companies, e.g. the Bombay-Burmah Trading Co. in British Borneo, and the Koetei Exploration Co. in East Borneo, began operations.

In 1901 the Royal Dutch began to drill in Koetei, and the East Borneo Co. a little later. The production of these fields rapidly increased, and had already reached a figure of nearly 60,000 tons in 1900. At the present day the production of Borneo is in the vicinity of 4000 tons per day.

There are at present three important producing areas in Borneo:

1. The Koetei area, extending from the mouth of the Mahakam River southwards towards Balik Papan Bay.
2. The Tarakan area, situated on the island of Tarakan on the east coast, about 80 miles south of the British North Borneo frontier.
3. The Miri area, on the west coast in Sarawak, about 150 miles south of Brunei Bay.

These three areas differ to some extent geologically, and considerably in respect to the types of oil they yield.

The oil-bearing rocks of the Koetei area are of Pliocene and Miocene age. They consist of Pliocene sands, gravels and clays laid down under delta conditions, the sands being dominant and the clays subordinate. Lignites containing a high water content (25%) are of frequent occurrence, as is the case in the Tarakan area also. Boulders of coal, of lower water content, derived from the lower Koetei formation also occur.

This series lies unconformably on the Miocene, which is made up of interbedded clays and sands, with frequent coal beds lenticular in form, all laid down under delta conditions. Below these strata is found the greensand formation, which consists of glauconite sands with interbedded foraminifera limestones, the age of which has not yet been definitely determined, but which are probably early Miocene. Below these, again, a marl, which is probably of Eocene age, similar to that found in North Borneo.

The Miocene and Pliocene were certainly laid down under delta conditions, the material having been brought down by large rivers such as the existing Mahakam, which flowed down from the central massif of Borneo. This massif, which is exposed in the S.W. of Borneo, and which almost certainly extends under the surface strata through the

centre of the island, is of igneous rock. On its flanks the Miocene and Pliocene deposits were laid down. Subsequent lateral pressure in a N.W. to S.E. direction gave rise to a series of folds in this area running N.E. to S.W., roughly parallel to the Macassar Straits. These folds appear as the well-marked anticlines of Sanga Sanga and Palarang.

The general folding process must have begun before the Pliocene rocks with lignites were completely laid down, so that the tops of the folds evidently appeared as islands in the Pliocene sea, and on being denuded supplied in part the material which was deposited in the tectonic troughs. The sinking of these troughs and the filling in of the same must have taken place at about the same rate, as is indicated by the uniformity of the strata traversed by the wells in the Tarakan field.

A further subsidiary folding was caused by lateral pressure in a N.E. and S.W. direction, which, however, was not so marked, so that the anticlines appear as very elongated domes. On these elongated domes the oil-fields are developed.

As already mentioned, the beds consist of sandstones and clays which were laid down under delta conditions, the sands thinning out generally towards the east. The beds of coal which are not continuous are of very frequent occurrence. In several cases oil has been obtained actually out of these coal beds.

The Koetei fields are developed particularly along the very well-defined Sanga Sanga anticline. This anticline runs from N. of the Mahakam to a point N. of Balik Papan, the crest extending 100 km., and is divided into two separate domes, the northern being the Sanga Sanga Moera dome with the Sanga Sanga Moera oil-field, and the southern the Sambodja dome, bearing the oil-field of the same name. There is a depression in the anticline between these two domes in the region of the Dondang River.

The older Miocene strata which underlie the upper Koetei delta series are not exposed on this anticline, but do crop out on the Palarang anticline, which runs parallel further inland.

In the Koetei fields three distinct types of crude oil are found, viz. heavy asphalt oils in the upper strata, light asphalt oils at greater depths and paraffin wax oils at still greater depths (Ragosin, *Pet. Rev.*, 1903). The nature of these oils and the significance of their distribution will be discussed later.

The structure of the Tarakan field is that of a system of two domes with a depression in between, the major axes of which run in a N.–S. direction. In this area, which is also of delta formation, Pliocene sand dominates. The field is developed in part of the delta which was nearer the coast and where consequently sands predominate, the interlying clays being not so well marked. Pliocene coals, or rather lignites, often

containing boulders of older coal from the late Miocene formation, are frequent. The oil from this field is markedly uniform in composition.

The Miri field lies on the west coast of Borneo. The geological structure here is not yet so well known as that of the two fields described above. There is a well-marked anticline, the eastern wing being very much the steeper. The oil is drawn from the western wing. The strata here are also of Miocene age, and coals are conspicuous by their absence.

The oils of the Miri field are fairly uniform in character, but differ fundamentally from those of the Koetei and Tarakan fields.

The crude oils of Koetei fall into three main classes:

(*a*) Heavy asphalt base crude oils.
(*b*) Light " " " "
(*c*) Light paraffin " " "

Numerous samples of oils from different zones in the Koetei field show gradations between the three types mentioned above. The heavy asphaltic crude oils of the Sanga Sanga anticline are found at relatively shallow depths, rarely below 900 ft. These oils contain practically no benzine fractions and yield no kerosene of commercial value. They are practically free from paraffin wax, and find commercial utilisation only as liquid fuels.

Sample.	A.	B.	C.	D.	E.	F.
Depth . . .	58 m.	104 m.	147 m.	108 m.	160 m.	339 m.
Sp. Gr. at 15° C. .	·959	·964	·959	·962	·957	·944
Volatile to 150° C. .	2·4%	—	—	2·2%	—	—
" " 300° C. .	33·8%	35·8%	37·2%	37·4%	32·1%	43%
Sp. Gr. of benzine fraction . . .	·804	—	—	·811	—	—
Per cent absorbed in 100% sulphuric acid	20%	—	—	26%	—	—
Sp. Gr. of residue .	·781	—	—	·751	—	—
Sp. Gr. of kerosene fraction . . .	·896	·896	·892	·897	·895	·885
Per cent absorbed in sulphuric 100% acid	22%	20%	28%	37%	—	—
Sp. Gr. of residue .	·875	·877	·862	·863	—	—
Sp. Gr. of residue over 300° C. . . .	·994	1·001	1·000	1·006	0·980	·994
Flow-point of residue	2° C.	2·5° C.	4·5° C.	3·5° C.	—	—

Samples C and D are from the Sambodja section of the anticline. F is a considerably lighter oil than the others and is an intermediate oil approximating to the light asphalt oil type.

At greater depths, on the same anticline, light asphalt oil is obtained in larger quantities.

Typical analyses of this class of oil are as follows:

Sample.	G.	H.	I.	J.	K.	L.	M.	N.
Depth	252 m.	363 m.	311 m.	270 m.	354 m.	337 m.	319 m.	298 m.
Sp. Gr. 15° C.	·889	·884	·882	·896	·864	·861	·895	·896
Volatile to 150° C.	17·5	26·8	23·7	22·6	25·7	24·2	7·6	14·4
„ „ 300° C.	78·1	79·9	79·3	77·3	75·6	75·8	62·6	77·7
Sp. Gr. benzine fraction	·815	·815	·812	·821	·786	·780	·742	·813
Per cent absorbed in 100% sulphuric acid	38	35	36	41	—	—	—	—
Sp. Gr. residue	·774	·776	·771	·781	—	—	—	—
Sp. Gr. kerosene fraction	·872	·882	·878	·888	·851	·852	·860	·860
Per cent absorbed in 100% sulphuric acid	46	44	44	45	—	—	—	—
Sp. Gr. of residue	·837	·838	·836	·845	—	—	—	—
Sp. Gr. residue over 300° C.	·980	·983	·979	·992	·980	—	·979	·985
Flow-point of residue	2° C.	2·5° C.	3·50	4°	—	—	—	–10° C.

From lower levels still in Sanga Sanga a large production of wax oil has been obtained, many of the crudes being very rich in paraffin wax. At Sambodja similar crudes are found also at similar depths.

Typical analyses are:—

Sample.	O.	P.	Q.	R.	S.	T.	U.
Depth	433 m	466 m.	362 m.	407 m.	382 m.	512 m.	503 m.
Sp. Gr. 15° C.	·852	·859	·863	·850	·881	·911	·855e
Volatile to 150° C.	25%	17·6	18·9	16·0	20·4	—	5·3
„ „ 300° C.	69·8%	60·7	71·5	73·6	74·0	34·0	37·0
Sp. Gr. of benzine fraction	·786	·772	·798	·785	·809	—	·777
Per cent absorbed by 100% sulphuric acid	28%	19	32	21	34	—	—
Sp. Gr. of residue	·749	·748	·762	·751	·769	—	—
Sp. Gr. of kerosene fraction	·853	·858	·858	·844	·873	—	·835
Per cent absorbed by 100% sulphuric acid	38	31	38	29	44	—	—
Sp. Gr. of residue	·803	·813	·815	·803	·831	—	—
Sp. Gr. of residue over 300° C.	·906	·904	·916	·905	·958	·926	·877ϕ
Flow-point of residue	41	44	41	40	16·5	32	38° C.
Per cent paraffin wax in crude	6·2	10·9	6·0	5·6	1·1	—	16·3

T Crude oil solidified at 20° C., an unusual type.
e Specific gravity at 30° C. ϕ Specific gravity at 40° C.
The kerosenes from all the Sanga Sanga oils burn with a very smoky flame in a Hinks lamp.

It is obvious from an inspection of the above and many other analyses that the crudes of the Koetei field may be roughly divided into three groups, that the members of each group display considerable variation, and that crudes intermediate in character and showing gradations from one type to the other are common. A similar change in character with depth is found in the Alsace fields, where asphalt is found at 200 ft., heavy oil at 300 ft. and lighter oils at greater depths (Surny-de-Bonnier, *Eng. and Mining Journal*, Nov. 6th, 1920).

In general, however, the crude oils of the Koetei field have one character which differentiates them from most other crudes so far known. The specific gravities of the distillates, particularly of the more volatile fractions, are much higher than those of corresponding distillates from most other crudes. The same applies to the refractive indices. These characters, and the inability of kerosenes produced from these crudes to burn in any ordinary lamp without arrangements for an extra supply of air, were naturally soon discovered (Ragosin, *Pet. Rev.*, Vol. 8, 1903, p. 59).

The reason for this has long been well known. It is the presence of unusually large proportions of aromatic hydrocarbons in these oils (Steuart, *J.S.C.I.*, 1901, p. 989). The occurrence of aromatic hydrocarbons in crude oils has long been known, e.g. Charitschkoff (*Centralbl.*, 1899) made aromatic nitro-compounds from Grozny petroleum, and Zaloziecki (*Zeit. für angew. Chem.*, Vol. 20, p. 1765) from Galician crudes. Young (*J. Chem. Soc.*, 1898, p. 914) found aromatics in American petroleum. In fact, aromatic hydrocarbons have been found in small quantities in most crude oils, but seldom to an extent greater than 15 per cent, usually to a much less extent.

Jones and Wooton in 1906 (*J.C.S.*, Vol. 91, p. 1146) examined Koetei oils in some detail. They fractionated the distillates and found that, while the volatile fractions (35° to 60° C.) consisted of paraffin hydrocarbons for the most part, the higher fractions contained also naphthenes and rather extraordinary quantities of aromatic hydrocarbons, amounting to as much as 40 per cent. They identified benzene, toluene and m-xylene.

Tausz (*Zeit. angew. Chem.*, Vol. 32, p. 361) isolated from Borneo benzine all three xylenes and ethyl-benzene, the percentage of the meta-xylene present being four to five times that of the other compounds. Jones and Wooton also identified naphthalene derivatives, β methyl-naphthalenes and dimethylnaphthalenes, the percentage of naphthelene hydrocarbons in the crude amounting to about 6 per cent to 7 per cent. They concluded that these crudes, or, at any rate, their volatile fractions, were composed of paraffins, naphthenes and aromatic hydrocarbons in approximately equal quantities.

Chavanne and Simon (*Comptes Rendus*, 1919, p. 285) recently examined Borneo benzine fractionated at the refinery at St. Louis du Rhone by the French Service des Poudres. They claim to have identified cyclopentane, methylcyclopentane, cyclohexane, dimethylcyclopentane, methylcyclohexane and dimethylcyclohexane, and to have shown the practical absence (less than 0·05 per cent) of unsaturated hydrocarbons. Ross and Leather (*Analyst*, Vol. 31, p. 284) in examining Borneo gas oils identified decahydro- and tetrahydronaphthalenes.

The chemical examination of the very complex mixture of hydrocarbons and other bodies which constitute a crude petroleum is a problem of great difficulty. It is unfortunate that the method usually applied in practice for the separation of the constituents, viz. distillation, is one which is very liable to bring about chemical changes in the oil, so that the composition of the distillates is not necessarily the same as that of the crude from which they are obtained. Distillation, however, especially under reduced pressure, affords the only practicable method of separation as yet available. Separation of constituents by the differential action of solvents is a method which may give some results, as also might, to a less extent, selective adsorption by filtration through fuller's earth or some similar material. It is consequently the more volatile fractions of these petroleums which have so far been subjected to examination, and even the examination of these presents some difficulties. Tizard has recently developed a method, based on the work of Chavanne and Simon, for the estimation of aromatic hydrocarbons in the volatile or benzine fractions, dependent on the different solubilities of paraffins, naphthenes and aromatics in aniline. Details of this method have recently been published in the *J.S.C.I.*, Vol. 40, page 20T.

By the application of this method he has found the composition of the benzine fraction of Koetei oils to be paraffins 26 per cent, naphthenes 35 per cent, aromatics 39 per cent.

This benzine is a product made from both light asphalt and wax crude oils.

All three types of Koetei crude are similar in the main in containing aromatic hydrocarbons in large proportions. It is, however, to be noted that the aromatic content is, on the whole, lower in the wax crudes than in the light asphalt crudes, the significance of which will be discussed below.

Zaloziecki and Hausmann (*Zeit. ang. Chem.*, 1907, p. 1761), on the contrary, found that in the case of certain Galician petroleums the content of aromatics varied directly with that of the higher paraffins.

In this connection it is interesting to note that the high aromatic

content of Koetei oils, which some years ago rendered them of comparatively low value, eventually proved to render these oils of the greatest importance to the British Empire as a source of toluene. A brief description of the method of extracting the toluene employed during the war and of the present method of working up this crude will perhaps be of interest.

The Borneo benzine imported into England during that period had a specific gravity of 0·783, about 20 per cent by volume boiling up to 100° C., and final boiling-point 165° C. It contained about 40 per cent of aromatic hydrocarbons, about 7 per cent benzene, 14 per cent toluene, 15 per cent xylenes and 4 per cent of higher aromatics.

The benzine was submitted to fractional distillation in steam stills fitted with Heckmann columns of the normal type.

Each still had a capacity of about 30 tons of benzine, and was heated by three nests of steam coils of a heating surface of about 500 sq. ft. Each still was provided with a Heckmann column 18 ft. high, 5 ft. diameter, containing twenty-three trays, each fitted with forty-six cups.

Each still was provided with a dephlegmator 10 ft. high, 3 ft. 3 in. diameter, containing tubes with a cooling surface of 400 sq. ft. and with a tubular condenser of 900 sq. ft. of cooling surface. The working off of a charge in such a still occupied about twenty-one hours. The distillation was conducted rapidly at first, and then more slowly as toluene began to appear in the distillate. At a certain point, controlled in practice by the specific gravity of the distillate (0·775), this was allowed to flow into a separate tank until such time as the specific gravity reached a figure (·800) indicating that the content of toluene in the distillate was sufficiently high to enable a fraction to be collected which required no redistilling. The first fraction so collected was termed light once run toluene-distillate, and amounted to about 10 per cent of the crude benzine. The distillate beyond this point was then collected separately until it had reached the maximum (about ·820) and dropped, with decreasing toluene content, to about 800 again. This cut, which amounted to about 12 per cent of the crude benzine, was sufficiently rich in toluene for the finished product. A further fraction was thus collected smaller in quantity, about 5 per cent of the crude, until the toluene content dropped below an economic figure (specific gravity of distillate 0·780). This fraction was termed heavy once run toluene-distillate.

The light once run toluene-distillate was then topped in a fractionating still until the residue was of sufficiently high toluene content to be added to the finished product. The heavy once run toluene-distillate was also fractionated, the distillate in this case being collected and added to the finished product.

The finished product, toluene-distillate, so obtained, boiled between 105 and 115° C. and contained about 58 per cent of toluene, being quite free from benzene and xylene.

This toluene-distillate was then converted by nitration into a mixture of mononitro toluene and unaltered benzine. The residual benzine was removed from the mixture by distillation, and the mononitro toluene further nitrated to the trinitro product.

The yield of toluene so obtained amounted to about 12½ per cent, i.e. about 90 per cent of the quantity in the benzine.

Large quantities of xylene-distillate, a product boiling between 128 and 145° C. and containing about 55 per cent of xylene, were also prepared by carrying the distillation further in a similar manner; but in this case merely the direct cut from the first distillation was isolated, there being no need to extract the maximum quantity in this case. In France also (*Nature*, 1921, p. 832) Borneo benzine was worked up to yield benzene, toluene and xylene.

The manufacture of toluene from Borneo benzine has now been discontinued. Recent research on the efficiency of various benzines as fuels for internal combustion engines has demonstrated the special value of the aromatic hydrocarbons in this connection. It is well known that aromatic hydrocarbons can be used in an engine of higher compression ratio, and therefore of greater efficiency, than can hydrocarbons of the other two classes, naphthenes and paraffins.

The researches of Ricardo, now being published in the *Automobile Engineer*, have demonstrated the superiority of toluene in this respect, xylene being less efficient than toluene, but more so than benzene. The high aromatic and especially toluene content of the Koetei benzine renders it, therefore, particularly suitable for engines of relatively high compression ratio.

In the early days of the industry in Borneo the Koetei crudes were worked up into a motor spirit, the valuable properties of which were not at the time realised, a kerosene of poor illuminating quality and liquid fuel. Later, a wax plant was added, and the wax crudes are now worked up into paraffin wax of grades varying in melting-point from 47 to 60° C. Further, large quantities of batching and lubricating oils are now manufactured from Koetei wax crude.

The difficulty of obtaining a kerosene from Koetei crude, which will burn in the ordinary lamps on the market, has been got over by the erection of a large Edeleanu plant. By this means a kerosene low in aromatic content and of good burning quality is obtained.

The crude oils of the Tarakan field are comparatively uniform in character and show little variation with depth. They are all of asphalt base type. The specific gravity varies from ·955 to ·942. They contain

no benzine fractions, and have a flash-point in the vicinity of 100° C. They are of low viscosity, and are quite liquid at −10° C. They contain only traces of asphalt insoluble in alcohol-ether, and have a low coking value. They form excellent liquid fuels and are used almost entirely for this purpose. They are also used successfully in Diesel engines, and can be distilled for lubricating oils.

A typical analysis of Tarakan oil is as follows :—

Specific gravity at 15° C.	.	.	·945 to ·950
Viscosity Engler at 50° C.	.	.	2
„ Redwood II at 0° C.	.		120
Asphalt insoluble in alcohol ether	.		0·6%
Coking value	.	.	4%
Sulphur	.	.	0·3%
Distilling up to 220° C.	.	.	0·8% sp. gr. ·852
„ 220°–240° C.	.	.	3·1% „ ·870
„ 240°–260° C.	.	.	6·6% „ ·886
„ 260°–280° C.	.	.	9·4% „ ·900
„ 280°–300° C.	.	.	10·1% „ ·914
Aromatic content in fractions to 280° C.	.	.	32%
Percentage of the kerosene fraction absorbable in 100% sulphuric acid			32

The crude oils of the Miri field differ fundamentally from those of the Koetei fields. Miri crude is a thin, mobile oil, brown in colour and by no means opaque. It yields about 20 per cent of a benzine low in volatile fractions, 30 per cent or so of kerosene and a thin residue of low, cold test.

A typical analysis of Miri crude is as follows :—

Specific gravity at 15° C.	.	.	0·890 to 0·925
Asphalt insoluble in alcohol ether	.		Nil
Sulphur	.	.	0·4%
Viscosity, Redwood II at 0° C.	.		45 secs.
Distilling up to 120° C.	.	.	2·6% sp. gr. 0·754
„ 120°–140° C.	.	.	3·3% „ 0·767
„ 140°–160° C.	.	.	6·7% „ 0·778
„ 160°–180° C.	.	.	8·0% „ 0·794
„ 180°–200° C.	.	.	6·9% „ 0·814
„ 200°–220° C.	.	.	6·9% „ 0·833
„ 220°–240° C.	.	.	6·0% „ 0·856

Distilling 240°–260° C. . . .	6·8%	sp. gr. 0·878
„ 260°–280° C. . . .	10·3%	„ 0·896
„ 280°–300° C. . . .	7·1%	„ 0·913
Percentage of the kerosene fraction absorbable in 100% sulphuric acid	25	

In this case, again, little work has been done on the chemical character of the oil, definite information concerning the volatile fractions only being available. These are composed almost entirely of naphthenes. An analysis of the benzine fraction gave the following results :—

Specific gravity at 15° C.	0·765
I. Boiling-point	60° C.
Boiling to 100° C.	7%
„ 120° C.	55%
„ 140° C.	83%
„ 160° C.	94%
Final boiling-point	180° C.

The chemical composition of this spirit was as follows :—

Benzene	0·4% by weight.
Toluene	1·9% „
Xylenes	1·5% „
High aromatics . . .	1·0% „
Naphthenes . .	about 80% „
Paraffins . . .	„ 15% „

The benzine being thus of particularly low paraffin content. The residue, after removal of the benzine and kerosene fractions, is a thin fuel of viscosity R. II at 0° C., 200 secs.

The question of the relation of the chemical composition of a crude oil to its origin is always one of extreme interest, and at the same time, one might say, of extreme difficulty. The consideration of a few generalisations drawn from a study of the occurrence and characters of the crude oils of Borneo, particularly of the Koetei field, may be found to throw a little light on, or perhaps one should say, to offer a few suggestions relative to this important question.

The crude oils of the Koetei field were either developed in situ, or else migrated from some mother rock into their present reservoirs. If these oils were found in situ, then they must be of vegetable origin, as there is no indication in the sands and coals of sufficient animal matter to have yielded such quantities of oil. Further, had they developed in situ, they must have arisen either from the coal or from the vegetable matter which formed the coal. Experience does not lead one to expect that

they have been formed from the coal, and the change of vegetation, partly into coal, partly into oil (the two products being coexistent), is equally contrary to experience. Mabery, however (*Jour. Amer. Chem. Soc.*, 1917, p. 2015), expresses the view that the results of the distillation of Deerfoot coal *in vacuo*, and the similarity of the distillates to those obtained from Mahone petroleum, in the vicinity of which coal is found, indicate that the coal is an intermediate state of decomposition between vegetable substances and petroleum, a close relation of coal to petroleum appearing extremely probable in this particular case. Mahone petroleum was found by Mabery (*Jour. Ind. Eng. Chem.*, 1914, p. 101) to consist almost entirely of hydrocarbons of the series CnH_2n-2 and CnH_2n-4.

The other view, that the oils migrated into their present position, is much more probable, and is supported by certain evidence afforded by the differences in composition of the crude oil from different horizons.

Conditions advantageous to migration exist in the Koetei and Tarakan fields. In the former, clays and sands alternate, but the layers are discontinuous owing to their formation under delta conditions, so that a zigzag course is open to the oil migrating upwards, there being, however, many opportunities for retaining portions of the oil under impervious clays *en route*.

A probable source of the oil is to be found in the foraminifera limestone (which is a shallow water deposit accumulated quickly) of the early Miocene, or possibly in the marl formation of the underlying Eocene.

It is possible that as the oil migrated upwards, coming into contact with or passing through the coal beds, some chemical interaction between the oil and the coal may have taken place. One might expect, therefore, differences in composition of the oils which have been arrested in their upward course by local obstacles at different horizons. This is, indeed, undoubtedly the case. As has been pointed out, the oil found at the greatest depths so far drilled, is rich in paraffin wax. The oils found at higher levels are poorer in paraffin and richer in aromatic and asphaltic constituents. Broadly speaking, the greater the degree of migration the lower the paraffin content and the higher the aromatic and ashphaltic content. The early Miocene greensand formation, which underlies the Koetei petroliferous formations, has not yet been penetrated by borings, but it is found outcropping in the Palarang anticline, which runs parallel to that of Sanga Sanga, some miles further inland. The nature of the oil found there in these lower strata is in accordance with the view above put forward. This oil had the relatively low specific gravity of 0·831, yielded 40 per cent of a kerosene of specific gravity 0·809, which burnt well in a Hinks lamp,

and which was of very low aromatic content. The crude was, moreover, rich in paraffin wax. This oil comes from a level below the coal-bearing strata. These facts suggest the possibility of the paraffin-rich and aromatic-poor oil having undergone some chemical interaction with the coal in its passage upwards, which resulted in a diminution of the wax content and increase in the aromatic and asphaltic constituents. It is difficult to understand in what way such a change could have come about. The facts, however, exist and need some such explanation.

It is interesting to note that in the Miri fields, where coals are absent, the oil is relatively low in aromatic and asphaltic content. This statement must, however, be made with a certain amount of reserve, as the sp. gr. and refractive indices of the higher boiling distillates show great similarity to those of the Koetei oils. That the oils of Perlak, in Sumatra, where coals are absent, are lower in aromatic and asphaltic content than those of Moera Enim, in which field coals are present. The fact also that the difference in character with increase of depth is so very much less marked in the Tarakan field, where the geological conditions are much more favourable for easy migration, lends support to this idea, as does also the character of the kerosene fraction.

The views expressed above can hardly be put forward as a theory; the facts on which they rest are insufficient, and no details have been worked out. They can merely be regarded as a suggestion, and indicate lines along which profitable research might be carried out. They serve rather to emphasise our ignorance of the fundamental chemistry of petroleum and of the methods of its formation.

In conclusion, I wish to acknowledge the great assistance given to me by the geological staff of the Balaapeke Petroleum Mij. in working up this paper.

DISCUSSION.

The President, in proposing a very hearty vote of thanks to the author for his excellent paper, said he had told a story in a calm, dispassionate, scientific way about a subject which, as many present would remember, was one of the great pieces of organization that was done during the war: he referred to the manufacture of T.N.T. He desired particularly to refer to that subject, because within the last few days Lord Moulton had passed away. It fell to Lord Moulton, as head of the High Explosives Department first at the War Office and then at the Ministry of Munitions, to organize the production of high explosives generally. T.N.T. came not only from the Borneo oils but also from gas works; and he remembered on one occasion, when he was in the Ministry of Munitions, the branch that had in hand the

organization of the filling of shells with high explosives urgently needed to know what particular mixture could be obtained by a certain date, because upon that depended the kind of plant with which the factories had to be equipped. He remembered going to Lord Moulton and asking him the question, and he received the reply that from four or five months ahead he would receive a particular mixture containing a certain proportion of pure T.N.T., and that he would receive certain quantities of that for the rest of the war. On the strength of that opinion the Department went to work and the whole of the filling factories were organized, except those that were engaged on lyddite filling, on that *ipse dixit* of Lord Moulton's. That *ipse dixit* was fulfilled absolutely to the letter, due not only to Lord Moulton's great attainments and the extraordinary way in which he organized the chemical industries, knowing exactly what each was capable of producing, but because of the fine organizing work that was done by men like the author of that evening's paper and his Company and others associated with him, and, of course, also by the great English gas companies. That magnificent piece of organization which gave the Allied Armies the quantities of high explosives they needed stood out as one of the great romances of the war. It might also be of interest to point out that the Dr. Jones to whom the author had referred was a member of Lord Fisher's Oil Fuel Committee; he went on a tour to Switzerland with his bride and they were both killed there in an accident. The only question he desired to ask was whether 1906 was the date of the first discovery of toluene in Borneo oils.

Mr. Kewley said he found it rather difficult to answer the question, because it might have been known previously.

The President said the point of interest was that whatever might be the exact date, the discovery was a very timely one, as events proved in the war.

Dr. Ormandy thought the paper was of tremendous interest because it threw light on fundamental problems. Many of the papers which had been given recently at the Institution were rather of the "scissors and paste" type, and it was quite a change to hear one which was based on new and original work dealing with fundamental problems. With reference to the author's statements at the beginning of the paper, he thought very few people, even chemists, realized to what an extent oils were decomposed even in distillation at a low temperature. A very interesting parallel case which was not well known was that if the gases given off from a coal retort were gradually and carefully cooled sufficiently to allow all the tars to separate, the heavy oils being allowed to pass on by fractional condensation, a tar was obtained which contained no free carbon, and which was entirely soluble in benzene.

If, however, the tar was heated in a porcelain basin to a temperature of 200° or 300° C., as much as 22 per cent would be found to be insoluble in benzene with half an hour's heating. A similar action took place in a lesser degree with oils, and it was desirable that investigators of new samples of oils or workers in an original direction should as far as possible carry out their distillation under the highest possible vacuum, in order to get the least temperature decomposition, if they desired to examine their samples with a view to correlating their results with that of the original oil. The method recently developed by Tizard for the quantitative estimation of the ratio of benzene, toulene, xylene, and naphthene in oils was of very great interest, and was exceptionally simple to carry out, namely, the critical temperature or the critical percentage at which the oil and aniline would separate. Personally he had carried out certain experiments, the results of which he hoped to bring before the Institution shortly, on the relative solubility of alcohol containing a small amount of water with benzene, toluene, xylene, and petrols of various character, and he found that very similar results were obtained to those obtained by Tizard, but the influence of each ingredient was different in the case of water and alcohol to what it was in the case of aniline, and the utilization of the two in parallel might give an additional means of estimating those very complex mixtures. The author referred to the fact that recent research on the efficiency of various gasolines as fuel for internal combustion engines had shown the value of aromatic hydrocarbons. Those who used motor-cars realized that by utilizing a mixture of commercial benzol and petrol better results were obtained from the engine. Long before that was recognized in this country, the French racing motor-cars used a mixture of 1 part of commercial benzol to 2 parts of petrol. Owing to the foolish attitude taken up by the Government in taxing engines on the diameter of the cylinder, motor manufacturers used the highest possible compression to get the biggest energy from a given size of cylinder. The result was that manufacturers used too high a compression for long and efficient running on average fuel. By adding benzene it was found that the pressure at which detonation took place was increased. In other words, in the case of paraffin petrols when the gas was compressed and fired by means of a spark the pressure immediately rose, the curve became almost a vertical straight line, and there was a very rapid generation of pressure and a pinking noise occurred in the engine. The very accurate researches carried out by Mr. Ricardo had shown that toluene had almost the greatest effect of any material tried in reducing that tendency to detonation instead of the desired gradual progression of a combustion wave. The only materials tried which were better than toluene were alcohols, and as he was par-

ticularly interested in the use of alcohol he desired to take the opportunity of mentioning the fact. Incidentally he might say that those people who had to put on the market a petrol containing a high percentage of paraffin, which was the most sensitive to preignition might in the future have to add a certain percentage of alcohol in order to reduce the tendency to detonation to enable their petrols to be used for aeroplane purposes. Unfortunately, however, the alcohol that was added did not have the same heat content as the toluol which might be added but which Nature had kindly put in the right proportion into some petrols. He would like to ask the author what happened to those unsaturated bodies which were taken out by the Edeleanu sulphur dioxide process. There must be a considerable quantity taken out of the kerosene in order to leave nothing but the paraffin bodies behind. In referring to the Tarakan oils, the author said they were all of asphalt base type, and went on to say that they contained only traces of asphalt insoluble in alcohol ether. He presumed that by saying they had an asphaltic base they would probably prove, or had proved, to have a high asphaltene value. He would like to know whether that was so and what constituted an asphaltic base oil which contained no measurable amount of asphaltic bodies. The most interesting portion of the paper to him was that in which the statement was made that near the surface oils which were heavy and ashpaltic were obtained; that lower down light asphaltic oils were present, and lower down still paraffin base oils. It would be remembered that Mr. Garner, in the paper he gave before the Institution, worked out a method for estimating asphaltic materials and asphaltene in oil by selective adsorption of charcoal, and he referred to the fact that it was well known that charcoal selectively adsorbed paraffin wax. If the oils contained much paraffin wax and had to percolate up along a passage in contact with carboniferous material, i.e. lignites, it was quite possible that the lignite base had acted as a selective filter and had taken out the paraffin wax content. He desired to point out also that in the recent patent specification of the great authority on colloidal fuels the claim was made that by mixing coal-dust with an oil having a given flash-point, the flash-point was raised. He had a very strong suspicion that if 40 per cent or 50 per cent of sand or other finely divided material were added somewhat similar results would be obtained, and he was having that experiment carried out. If such a result were due to selective adsorption, the volatile portions of the oils coming up through a huge area of finely divided sand, which contained a lot of clay, were exposed to an enormous adsorptive surface, and it was quite possible that a selective adsorption of the light volatiles and of the pure paraffin wax contents was obtained. That might account for some of the results, but it would not account

for the fact that the benzene bodies, the ring bodies, were increased near the surface. The paper brought out the point that it would be a most interesting experiment to try the effect of temperature and pressure on the action of a paraffin base oil on some of those particular lignites, with a view to seeing what took place. It would be interesting to find out whether the lignites which were found in the oil areas through which the oil had passed showed any great variation in the percentage of material soluble in various solvents such as chloroform, aniline, etc., compared with similar lignites in the immediate vicinity not in the oil area.

Mr. Anfilogoff said the paper was of particular interest to him because probably he was the only person present, except the author, who had much to do with Borneo crude oils in the early stages. His first experience of Borneo crude oils was at the latter end of 1898 and the beginning of 1899, when he believed the first two or three freights of crude oil from Borneo were shipped by Sir Marcus Samuel to Thames Haven. On that occasion he found great difficulty in separating a kind of emulsion from the crude oil which he had never seen since, but it was passed off as being a sort of soapstone solution! In those days there were no electric separators or electric demulsifiers, and it was necessary to break up the emulsions in the stills, which was quite a difficult problem. He had learned a good deal about Borneo crude oils from the paper, and he desired to take the opportunity of congratulating the author on the addition he had made to the science of petroleum technology in general. The President had asked when the toluols were first found in the toluene-benzene. It would probably prove of interest if he stated that only that day he had seen a sample of nitro-benzene manufactured from Borneo spirit on March 4th, 1902. It was a sample which he prepared at that time for his Directors and which he came across in the course of the day. It might also be of interest if he stated the accidental way in which he first came across the aromatic hydrocarbons in Borneo spirit. When the first freight of Borneo spirit was brought to this country in bulk it was an achievement which caused great excitement. This was in 1901 and with others he had some samples *ex* that ship. Having been accustomed to the odour of Rumanian, Russian, and American petroleum spirit, the odour of Borneo spirit was foreign to him. He therefore attempted to refine it in order to "improve it" and, if possible, to correct the odour to that of American benzine. At the time he had a laboratory boy who was a very tidy person and, seeing two bottles on the table, both of which contained "acid" and only a small amount in each, the boy emptied one into the other and washed one bottle. But whereas one bottle had sulphuric the other had nitric acid, and when he (Mr. Anfilogoff)

attempted to use that mixture—not knowing what had happened—he was surprised to find that a portion of the spirit was nitrated and gave the familiar odour of nitro-benzene. This led him actually to nitrate a portion of the spirit, and he found a considerable quantity of aromatic hydrocarbons. After this a sample was distilled and the "benzene" fraction separated and nitrated and a pure sample of nitro-benzene was prepared by him early in 1902. He was not then interested in toluol, nor did he actually separate the toluol or xylol fractions.

Dr. Dunstan thought the paper opened two avenues of exploration in connection with petroleum, one a general avenue dealing with the origin of the substance, and the second more specifically dealing with the metamorphosis of the material. So far as the origin was concerned, it appeared to him that the Institution at some early date could very well spend a whole evening in a full-dress debate on the question, particularly as the views of geologists and chemists were apparently at variance. He was informed quite recently, after a geological lecture, that most chemists believed in what was called the inorganic origin of the substance, the old theory of Mendeléef; which was preposterous. It therefore seemed to him that everything was to be gained by an open discussion on such a very important matter. With regard to the metamorphic change of petroleum, it appeared to him absolutely incomprehensible that any filtration of petroleum through coal or lignites should remove saturated solid hydrocarbons, because Day and his co-workers in the States had shown rather the opposite effect, i.e. when petroleum was filtered through any adsorbent substance the first things that were taken out were the unsaturated reactive compounds, and so on. That one should begin to adsorb the paraffin hydrocarbons first appeared to him entirely out of the question, at any rate until the author could bring forward some definite information of actual experimental adsorption of the wax-bearing crudes with lignite dust or coal dust, showing clearly that wax was adsorbed by them. One would expect the very opposite to occur, namely, that the paraffin base crude was the initial substance and that, by processes of condensation, oxidation and combination with sulphur, the ordinary asphaltic material as it was now known was gradually produced. In point of fact the paraffin waxes were the most easily attacked of the components of petroleum. Paraffin wax could be cracked at extraordinarily low temperatures and oxidized easily. Personally he thought the original petroleum was a wax base oil, as Engler described in his researches on the hydrolysis and condensation of fish oils, and that by oxidation and in contact with sulphur and with adsorbent materials a mixed paraffin asphaltic base oil was produced which ultimately became a true asphaltic base oil and ultimately became both this and oxy-asphalts.

There were two or three points of detail to which he would wish to refer, first of all the isolation of toluol and benzol from petroleum. It might not be generally known that the aromatic hydrocarbons obtained from petroleum were extraordinarily pure. If aniline was made from coal-tar benzol, in a very short time the preparation turned red, brown, and black, but if nitro-toluol were made from petroleum the oil remained water white for months and months. He was told by practical T.N.T. makers at Oldbury that they ever so much preferred to handle the author's Borneo toluol benzene to the material, no matter how pure it was, which they obtained from the gas works. That was a very extraordinary thing which would certainly repay further investigation. With regard to the ratio of benzol, toluol and xylol mentioned on page 219, in investigating the aromatic contents of other oils, Persian in particular, he had found that practically the same ratio was obtained, i.e. toluol was in excess, and it was a singular thing that the xylol was mainly the meta-xylol. He believed that in coal tar also the meta-xylol was the main component. Apropos of analyses of oils, it might be of interest if he stated that for some years past he had been making ultimate analyses of crude oils, and he found on his list a Tarakan crude oil; and in looking down the carbon percentages he found that peculiar Borneo oil had the highest carbon content of any—88·1. The next nearest to it was an oil from Utah, 87·6, and Cannell oil, 85·6. The average carbon content of ordinary petroleum was round about 84 and 85. For instance, Burma crude was 83. Persian crude 83·4. Similarly the hydrogen content was on the low side, 11·6 per cent.

Dr. Lessing said that a few months ago Sir Arthur Duckham gave a lecture before the Institution and in the course of the discussion the late Sir William Ramsay's proposal to gasify coal underground by a kind of producer process was mentioned. Sir Arthur said he did not believe in it, but he stated that if anybody would indicate means whereby coal could be extracted from the ground by an organic solvent he believed that would be a more economical or possible method to adopt. Although personally he did not believe that, with the present price of organic solvents, anybody would pump them down into the earth and fetch up some constituent of the coal, at the same time there was an analogy to the theory or suggestion which the author had put forward. It had rightly been objected to, particularly by Dr. Dunstan, that one would not expect the paraffin wax to be left behind and the aromatic contents to be taken away from the coal and carried up. To a certain extent he agreed with that, but not for the reason suggested by Dr. Dunstan. In his opinion the paraffins were the least efficient coal solvents, and for that reason one would not expect the paraffin wax to be left adsorbed in the coal and the more aromatic constituents to be

withdrawn from it. The question of adsorption did not seem to him to be the most important one, because coal could not be regarded as anything in the nature of charcoal, for instance, which would have an adsorbing effect. Only a small portion of coal consisted of a charcoal-like compound, fusain.

Dr. Ormandy pointed out that it was not coal but lignite.

Dr. Lessing said he thought that was not entirely the case. He presumed that the lignites were only on top.

Mr. Kewley said they were all geologically young coals.

Dr. Lessing said that one had to deal in lignites with an intermediate state in coal formation, while possibly the very process that the author expected to have taken place might have occurred at even a yet younger period of the coal during the action of coal formation, a period still more antecedent to the state in which the lignites were found at the present day. They had therefore not to deal with anything like a powdered coal sample, but with a formation possibly of the original plant debris or vegetable matter from which the lignites or coals had been formed. In that condition it was not at all unlikely that the deposits would be penetrable by the oil and would be amenable to some mixing or leaching process by the oil. In the absence of experimental data he would not like to make too much of the suggestion which even the author did not regard as a theory. He had been urging the author for some weeks past to try and get some experiments made in the first instance for the purpose of investigating the character of the coals which were there. At present nothing was known at all about that. The only fact given was the 25 per cent water content. In any event there seemed to be some connection between the oil deposit and the carboniferous deposit. Some confirmation of that theory seemed to lie in the fact that aromatic compounds were obtained quite apart from the richer asphalt content of the oil. In that connection it seemed to him it might be of value to compare recent researches on the formation of the aromatic compounds from oil. A new theory had been propounded by Fisher that they were not entirely formed by thermal decomposition of hydrocarbons, but by decomposition of the phenols, and therefore probably as a secondary decomposition of cellulosic compounds from which the coals were actually formed. That suggested that the penetration might have happened at a very early stage of the coal formation. In any case it seemed to show that there was a closer relation between oil and coal than had been assumed hitherto. Mabery's paper, which had been referred to by the author, showed something in a similar direction, and it was only possible to say that the rule of the Institute which recognized that all those interested in the manufacture or investigation of oils, whether produced from petroleum or coal, might

be members of the Institution, would be proved to be justified by events. A close connection might be found between them, and the clearing up of that connection would help to solve the problem both on the oil and on the coal side.

Mr. W. Macnab said he had not any observations to offer on the origin or the special qualities of the petroleum that the author described, but during the war he had a great deal to do with the material which the author's company supplied for the manufacture of T.N.T., and, as the President had remarked, many interesting points arose in connection with it. One of them was the extreme rapidity with which the Asiatic Petroleum Company, under the powerful suggestion of Lord Moulton, transferred their distilling plant from Holland and set it up at Portishead. Within a period of three months the refinery was transferred, and a factory was put up by the Government capable of producing about 250 tons per week of T.N.T. The two operations matured simultaneously. That was the beginning of the wonderful production of T.N.T. from Borneo petroleum. It was one of the most interesting things connected with the war to see the regularity with which the petroleum containing about 58 per cent of toluol came in and produced such an admirable source of supply of high explosives.

Mr. Evans said that he believed that Dr. Ormandy shared the opinion which he held, namely, that the use of the terms "paraffin base oils" and "asphaltic base oils" were loosely applied in the paper. Perhaps Mr. Kewley may be excused for his laxity on the grounds that the erroneous use of these terms is so commonplace. One hopes that Mr. Kewley will feel the need of revising his nomenclature. It is very necessary that these two terms should not be so freely used, for it is often said, by people outside the Institution, that members of the Institution do not know the difference between paraffin base oils and asphaltic base oils. If the terms are to stand then we must clearly define them, but if we cannot define them then they must be erased from our vocabulary. In view of the recent work upon the subject I am inclined to think that the terms cannot be defined, therefore should not be used.

He would like to know how the author determined the coking value referred to in the paper. The value of the coke test has yet to be established, certainly comparatively little work has been done to prove its usefulness. Dr. Ramsbottom has made an investigation of the various methods of test, including the Conradson, with not very satisfactory results.

He presumed that the analyses of the spirit were made by the aniline method.

Professor Brame said he felt that petroleum technology was badly

in need of a new vocabulary, and its terminology must be revised sooner or later. Reference was made to "mononitro-benzene and unaltered benzine"; when it was spelt with an "i" it was pronounced benzene, and when it was spelt with an "e" it was benzene. Was it not possible to get rid of such terms, which in ordinary conversation it was impossible to distinguish the one from the other? Benzene and benzine meant totally different things. He would prefer that, if the word was to be retained, it should be pronounced benzīne. As it was at present, the confusion was not only overwhelming from the point of view of the spoken language but also in print. Over and over again confusion could be found in technical literature between benzene and benzine.

Mr. E. H. Cunningham Craig writes: This is a paper of great interest and importance, and I think everyone will agree that we have had too few papers of this kind. Its chief interest is the detailed account of the environments in which different oils are found. The main facts have already been published in both Germany and Hungary, but this paper gives detailed analyses which are of the very greatest value as evidence of how different oils occur and why. Similar evidence has, of course, been obtained from oilfields in other countries, but very seldom has the evidence been put forward in such great detail.

The shallow oils are highly inspissated; they occur in strata that have naturally favoured inspissation, and also migration from below. The middle oils we may consider as fairly typical asphaltic oils, unaffected by inspissation, and possibly in some cases slightly filtered. The paraffin oils are obviously different. From all the evidence available from oil-fields, there is a very strong indication, if not actual proof, that paraffin base oils are formed under higher pressure than oils of asphaltic base, and are therefore often found at greater depths. There are, of course, numerous gradations between the two. The large proportion of aromatic hydrocarbons is a most important point. There is evidence that the higher aromatic hydrocarbons are found by polymerization which we know occurs at depth, and which I have described as one of the processes in the complex action which we speak of in a general sense as inspissation.

The evidence in this paper does not seem to me to favour the idea of migration on a large scale from below, though in the sandier upper strata migration may have played an important part. I do not think that there is much justification for the idea that the coals or lignites can have had much effect upon the oil. Were this idea correct, we should expect more effect upon the lignite than upon the oil, and from a study of other countries where the transition stage between carbonaceous and petroliferous conditions overlap, no evidence of mutual effects between

lignite and oil have been observed. The lignites are to be regarded as finished products, which have reached the lignitic stage before the formation of petroleum commenced. We may take it, I think, that these various oils have been formed within certain limitations in close proximity to where they are found now.

It is to be hoped that other papers of this nature, giving detailed accounts of analyses of different oils found in one field, will be put before the Institution, as there is much of great scientific interest to be learned from data so carefully collected and tabulated as in Mr. Kewley's paper.

Mr. I. A. Stigand writes: Having formerly spent some time in the region of Borneo, principally referred to in Mr. Kewley's paper, although a long while ago (over fifteen years), and at a later date in North Borneo, the paper is of considerable interest to me and suggests some questions.

In regard to the age of the beds the oil-bearing series of the Sanga Sanga and Louise region would seem most probably to belong to the early Miocene, although fossils of value for stratigraphical determinations are lacking. The foraminiferal and glauconitic beds mentioned as appearing in the Palarang anticline, and as probably underlying the coal and oil bearing formation, are presumably those of the Orbitoidal series, also found near Balek Papan, as also in North Borneo, in which the general assemblage of organisms associated would appear to indicate an age somewhere at the top of the Oligocene, or at the base of the Miocene—or about the Aquitanian; as in the case of the similar series occurring so extensively over the East Indies, and indeed all round the tropics and so frequently associated with petroleum—occurring both above and below this horizon. It is not clear as to what are the beds referred to as the "marls probably of Eocene age" (possibly the Passir limestone series?): any evidence as to the presence of Eocene beds in Borneo would be of much interest and importance.

As regards subsidiary folding caused by lateral pressure in a N.E. and S.W. direction, I can remember little indications of such having taken place in the Mahakam region—although possibly such movements may have been the case in the region of Balek Papan. On the other hand, the flexures in the former region are remarkably regular, long, and straight in trend. They sink southwards, but only in a comparatively gradual manner, and as might be expected—since all anticlinal folds must, of course, eventually die out. The most elevated portion of the flexure, however, would appear to be in the vicinity of Sanga Sanga. The general trend of the folds are in a direction of about S.S.W. and N.N.E. With reference to the Sanga Sanga anticline being prolonged to the petroliferous outcrops in the Sambodja and thence, with a further deflection, to Balek Papan, in my time the anticlinal

region was mapped as far as beyond the Dondang, the average strike of the axis being about S. 15° W., and gradually sinking, from which it appeared that it would—gradually dying out—strike the coast to the north of the Sambodja—although low ground, swamps, and alluvium would there interfere with its further tracing. I do not know whether subsequent investigation has shown it to be otherwise—i.e. continued to the Sambodja and thence further deflected as far as Balek Papan—which, in view of the differing strikes, would not appear very probable. In regard to the Palarang anticline, although this is steep or uplifted in the neighbourhood of Palarang on the Mahakam River, I did not find this to be the case in an area of this anticline on the west of the Dondang, where visited and seen in a cursory expedition.

In view of the circumstance that these deposits are perhaps the most marked example of the association of a coal-formation with the occurrence of petroleum—where the petroliferous series are intercalated with numerous coal-seams—often of remarkable thickness, the presence of comparatively large quantities of hydrocarbons belonging to the aromatic series in the oils is of interest. A possible source of origin, however, may be sought in marine vegetation, which may have thrived in the intervening periods to those of the coal seams—since the former vicissitudes concerning the formation indicate secular oscillations about sea-level, during which large tracts of land would have been disposed within tidal limits, or under shallow water, thus providing conditions favourable to the growth of marine vegetation. The stratigraphical position and association with the orbitoidal beds (principally made up of orbitoidal and other foraminifera, together with algæ—such as lithothamnium) is, however, significant in respect of a possible origin. The wide-spread and frequent association of petroleum with such series of beds, at similar horizons all round the world, often also with glauconitic deposits (as, e.g. in the West Indies) must be more than fortuitous. But, as in the case of other deposits, it is not desirable to accept a single origin. Possibly some slow and partial distillation of the coal may have also in some measure contributed, in which case some explanation of the presence of aromatic compounds in considerable quantity would be explained, as also marine vegetation.

Mr. James Kewley, in reply, said that Dr. Ormandy had asked what happened to the aromatic bodies removed in treating the kerosene in the Edeleanu plant. Unfortunately at present they had found their way into the liquid fuels, a disgrace which might perhaps be remedied some day. He humbly apologized for having been very careless in using the words "asphaltic compounds." In following the text-book style one usually differentiated between paraffin base oils and asphalt base oils, but probably the terms paraffin base oils and non-

paraffin base oils would be more strictly correct. He had simply used the term " asphaltic compounds " to cloak his ignorance. He was not in a position to give more definite information about the position of those high constituents for the reason that he did not know anything about them. He heartily agreed with what Mr. Evans and Prof. Brame had said with regard to petroleum technology. It was unfortunate that the word benzine should have to be used, but if it was not used, what word could be substituted for it ? Petrol or naphthene would be equally inconvenient.

Dr. Ormandy suggested that the word gasolene might be used.

Mr. Kewley, continuing, said that whatever argument was brought forward against the use of one particular word would probably apply to all. The terms were used in a hopelessly loose way, and it was high time that something was done on the subject. He thought a very good object would be served if a meeting of Petroleum Technologists were called merely to discuss details of that kind. He had been much interested to hear from Mr. Anfilogoff that he was able to detect the aromatic compounds as far back as 1902. He remembered hearing from Mr. Anfilogoff on a previous occasion that he had found them, but he did not know it was as far back as nineteen years ago. Previously he did not know that anyone had noticed them much before 1905 or 1906. Dr. Dunstan had somewhat misunderstood the remarks made in the paper. He (the author) did not mean to put forward any theory ; he merely endeavoured to state a few facts and to suggest that there was a possibility of something having taken place. He agreed with Dr. Dunstan that it seemed impossible that the paraffins should have disappeared, but one could not see what else could have happened. Certainly if the oil came from some other source it did not come from above ; it came from below, and the paraffin oil was invariably always found at the base. As the oil migrated upwards the paraffin content was steadily lower and lower. How it had taken place he did not know.

Dr. Dunstan pointed out that Gurwitsch had made experiments by passing amylene over Florida earth and he obtained extensive polemorization.

Mr. Kewley said it was quite possible that something of that kind happened. Dr. Dunstan had also called attention to the high percentage of carbon in Tarakan oil. Unfortunately he had not brought any figures with him, but he was under the impression that the ordinary heavy asphaltic oils at Koetei were even richer in carbon content than the Tarakan oils. With regard to Mr. Evans' question as to how the coking values had been obtained, as far as he knew they were ob ained in the ordinary method by ignition in a platinum crucible, but in any case he did not attach great importance to the figures.

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